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INVESTIGATION OF CALCIUM MAGNESIUM ACETATE (CMA) AND SODIUM FORMATE (NaFo) FOR USE AS A DE-ICER AT TRANSPORT CANADA AIRPORTS

January 1989

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Un sommaire en français de ce rapport est inclus avant la Table des matières.

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16. Abstract

Recent concern over the impact of urea on the surrounding environment, when used as a de-icer, has resulted in the search for a de-icer with less severe environmental impact. This report reviews past and current research and development relating to calcium magnesium acetate (CMA). Sodium formate was later added to the scope of the study as this chemical shows potential in the highway environment. The urea, CMA and sodium formate knowledge base was analyzed to determine research gaps requiring further investigation before adopting widespread use of CMA or sodium formate in an airport environment.

The six areas of investigation for each de-icer was: aircraft materials compatibility; operational effectiveness; environmental impact; airport runway materials compatibility; cost/benefit; and, technical specifications.

The study concluded that, although significant research has been performed in the highway environment, very little alternative de-icer/anti-icer research has been conducted in an airport environment. As a result, research is required in all six areas of investigation to compare CMA and sodium formate to urea before a sound decision on a de-icing/anti-icing strategy can be made.

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16. Résumé

Devenu un récent sujet de préoccupation, l'impact écologique de l'urée utilisée en tant qu'agent de déverglaçage, a forcé les chercheurs à trouver d'autres produits chimiques dont les effets sur l'environnement seraient moins néfastes. Ce rapport traite des travaux de recherche et de développement qui ont été ou qui seront effectués sur l'acétate de calcium et de magnésium (ACM). La portée initiale de l'étude a été élargie pour inclure le formiate de sodium, produit qui semble très prometteur d'après les études effectuées en milieu routier. Toutes les données disponibles sur l'urée, l'ACM et le formiate de sodium ont été analysées afin de déterminer les travaux de recherche restant à effectuer avant d'autoriser l'utilisation de l'ACM et du formiate de sodium en milieu aéroportuaire.

Les six secteurs du programme de recherche étaient : la compatibilité avec les matériaux des aéronefs, l'efficacité opérationnelle, les effets sur l'environnement, la compatibilité avec les matériaux des chaussées aéronautiques, l'analyse coûts-avantages, les prescriptions techniques.

Les auteurs du rapport signalent que même si d'importantes recherches ont été effectuées en milieu routier sur les agents de déverglaçage envisageables, il est loin d'en être de même en milieu aéroportuaire. Par conséquent, pour qu'une décision rationnelle puisse être prise en ce qui concerne les agents de déverglaçage à utiliser, l'ACM, le formiate de sodium et l'urée devront faire l'objet de recherches comparatives dans les six secteurs précités.

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SUMMARY

In April, 1988 the Transportation Development Centre of Transport Canada in Montreal contracted SYPHER:MUELLER International Inc., to investigate calcium magnesium acetate (CMA) for use as a de-icer/anti-icer at Transport Canada airports. This report reviewed past, current and future research and development performed or being performed with CMA, compared CMA to the currently used runway de-icer/anti-icer (urea), and identifies research gaps requiring investigation before adopting widespread use of CMA in an airport environment. The scope of this report was expanded to include yet another potential alternative de-icing/anti-icing chemical which has gained recent interest for use on roadways: sodium formate (NaFo). The ultimate goal of this project was to develop detailed Terms of Reference documents addressing six predefined program areas. The Terms of References were submitted to the Transportation Development Centre in the form of working documents and are not available for general distribution. Following are the six program areas and their research and development requirements.

- **Aircraft Materials Compatibility**

  Testing done in accordance with Aerospace Materials Specifications (AMS) 1426A has identified CMA and NaFo as staining aluminium. However, independent tests also show that the tap water and distilled water used in the sandwich corrosion test as staining aluminium. An evaluation of the functionality of the test should be looked into before qualifying or disqualifying any further potential airport runway de-icer/anti-icer. The various procedures within the urea specification (AMS 1730A) have become more stringent over time. As a result, urea presently fails its own specification, however, no alternative currently exists.

  A second area identified as requiring attention was the engine ingestion concern. Although this concern was brought to our attention as a result of the sodium content of the sodium formate de-icer, no such engine ingestion tests have been conducted on urea or CMA either. Sodium or salt ingestion from the atmosphere into the hot end of a turbine engine combines with sulphur produced by the combustion process and produces Na_2S0_4. Sodium sulfate erodes super alloys. Contaminating the inlet air with the various chemicals and documenting their relative performance was an

identified R & D requirement. Gas turbine engine manufacturers have to endorse the chemicals used on and around aircraft or the airports won't use them for engine warranty reasons. Engine manufacturers Pratt and Whitney and General Electric reluctantly accept the products now used on runways.

- **Airport Runway Materials Compatibility**

Research conducted in the road environment for concrete and rebar compatibility was determined to be transferrable to the airport runway environment.

Concrete scaling was most severe with urea, followed by sodium formate and least with CMA.

Steel corrosion rate results placed CMA at the same level as distilled water and sodium formate at an even lesser rate when tested in new bridge decks or structures. In the highway environment, there remains the question of CMA's corrosion inhibiting properties when used on NaCl contaminated concrete and rebar. Thus, CMA's corrosion inhibiting properties when used on urea contaminated concrete and rebar needs to be determined. Urea's relative corrosion properties were not documented in any of the references reviewed. Urea's rebar corrosion properties relative to NaFo and CMA in a new concrete and a urea contaminated concrete environment need to be verified.

- **Operational Effectiveness**

Field trials conducted in the urban or rural roads environment give an indication of alternative chemicals de-icing performance. However, airports would not have the same traffic to help speed up the de-icing effect as city roads or highways. In addition, these highway field trials have not tested the chemicals' anti-icing properties. Nor can a highway maintenance fleet give the level of attention to a certain road area that an airport snow removal fleet can give a runway. These additional variables make it necessary to conduct specifically designed airport runway field trials.

The only field trials of de-icing/anti-icing chemicals conducted in an airport environment (Brunswick, Maine, 1988) by the Federal Aviation Administration (FAA) were deemed very preliminary and inconclusive . Plans to expand these much needed trials this winter are already in progress. Even though the plans include abrasives as well as chemicals in de-icing mode, there is a need to include monitoring the chemicals performance in an anti-icing mode. This anti-icing testing is a unique requirement to an airport environment.

- **Environmental Impact**

The substantial amount of environmental research and development work which has been conducted on CMA in a road environment appears to be applicable and transferrable to the airport environment. These tests include standard procedures documented in references such as Standard Methods for the Examination of Water and Wastewater[1] for aquatic toxicity, soil leaching as well as actual field plot experiments.

The University of Washington work [2] included laboratory and controlled field plot experiments which demonstrated CMA transport into and its effects on the environment. However, this study also lists the following issues which are in need of verification:

1) actual CMA concentrations and mass loadings that enter surface receiving waters with runoff and the extent of dissolved oxygen depletion that result

2) the extent of trace metal mobilization in actual exposed soils; concentrations of these metals occurring in soil water, groundwater, and surface runoff

3) acetate mobility in soils with actual application rates especially its extent and consequences in groundwater

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(1) "Standard Methods for Examination of Water and Wastewater", 16th ed., American Public Health Association, 1985

(2) Horner, R.R., "Environmental Monitoring and Evaluation of Calcium Magnesium Acetate (CMA)", University of Washington, April 1987

4) composition of the soil microbial community that develops with actual CMA additions

5) the rate at which soils become saturated with major cations

6) the impact of CMA on auatic biota

At present, the Federal Highway Administration (FHWA) has no plans to continue environmental research in this area. It was anticipated that the Strategic Highway Research Program (SHRP) will address these remaining questions in its present research program, The Evaluation of Procedures for De-icing Chemicals (H205).

Even though preliminary impacts were identified for sodium formate based on its similarities/differences with sodium chloride, sodium formate is a recent addition to the candidate alternative de-icer spectrum and needs to be evaluated with respect to its environmental concerns. Urea also needs to be subjected to these tests for a direct comparison.

- **Cost/Benefit Analysis**

Although some of the phenomena that affect a cost/benefit analysis performed for the road environment (i.e., concrete or rebar compatibility, vehicle corrosion, environmental impact) also affect an airport environment, the degree to which each is affected is quite different.

In combination with this "order of magnitude" difference between common key parameters, the airport environment cost/benefit analysis must accommodate additional variables such as:

- rerouting or delay costs as a result of runway closures
- aircraft deterioration

Delay costs has been addressed in previous studies (i.e., airport applications for upgrading instrument landing systems are based on a thorough cost/benefit analysis performed by Transport Canada). However, delay costs have not been input into a cost/benefit analysis for airport snow and ice control.

In summary, an airport environment benefit/cost analysis is significantly different from previous highway environment economic work that a thorough, ground-up, first-principals type approach must be undertaken on a local level such that Transport Canada can make a de-icing chemical decision on an individual airport basis.

- **Technical Specifications**

A series of standard, comprehensive tests needs to be developed by the SAE/FAA or Transport Canada that would qualify any solid de-icing/anti-icing chemical for use on airport runways. A research effort in the United States funded by SHRP (project H-205: Evaluation Procedures for De-icing Chemicals) is moving in that direction for the roads environment and it is anticipated that a large number of the evaluation procedures resulting from this 3-year project could be transferable to an airport environment. Results from this project should be available in early 1991. Unique but important airport considerations that should be researched and appended onto a project such as H-205 could be:

- airframe and power plant materials considerations
- anti-icing vs de-icing capabilities.

For the airport environment, a committee has been established in the United States to rework the present series of Aerospace Materials Specifications (AMS 1426A for liquid runway de-icers/anti-icers) and redefine AMS 1730A (urea) to accommodate any solid runway chemical. Progress has been slow in this area up until now. However, a new draft specification (J88BM) has been submitted to the SAE and the committee appears to be moving faster now than in the past.

The study concluded that there was very little information directly comparing the performance of urea to any potential alternative runway de-icer/anti-icer in the highway environment. This fact was also true for the airport environment. The relative performance of urea to CMA and sodium formate in an airport environment, for the most part, is speculative based on previous highway research results. Therefore, it is recommended that research on the gaps identified be investigated before Transport Canada could endorse the wide-spread use of CMA or sodium formate.

SOMMAIRE

En avril 1988, le Centre de développement des transports de Transports Canada a chargé la compagnie Sypher:Mueller Internatioal Inc. d'effectuer une étude sur l'acétate de calcium et de magnésium (ACM), en vue de son utilisation comme agent de déverglaçage dans les aéroports de Transports Canada. Ce rapport traite des travaux de recherche et de développement qui ont été ou qui sont effectués sur l'ACM, compare ce produit à l'agent de déverglaçage (urée) utilisé actuellement sur les chaussées aéronautiques et identifie les travaux restant à effectuer avant d'autoriser l'emploi de l'ACM en milieu aéroportuaire. La portée de l'étude a été élargie pour inclure un autre agent de déverglaçage chimique envisageable, le formiate de sodium (NaFo), qui a récemment attiré l'attention par son utilisation sur le routes. L'objectif de ce projet était d'élaborer des documents de définition détaillée des travaux à faire dans six secteurs prédéterminés du programme de recherche. Les documents de définition ont été soumis au Centre de développement des transports sour forme de documents de travail et ne sont pas disponibles pour distribution. Les besoins en R&D dans chacun de ces secteurs son récapitulés ci-dessous.

- **Compatibilité avec les matériaux des aéronefs**

  Les essais effectués conformément à la norme "Aerospace Materials Specification 1426A" ont montré que l'ACM et le NaFo tachaient l'aluminum. Cependant, d'autres essais ont établi que l'eau du robinet et l'eau distillée, utilisées dans les essais de corrosion de piéces superposées, tachaient aussi l'aluminum. Une évaluation de la validité de cet essai devrait être effectuée avant d'en faire un critére de choix parmi les agents de déverglaçage envisageables pour les chaussées aéronautiques. Les différentes procédures d'essais

que contient la norme sur l'urée (AMS 1730A) sont devenues plus strictes au fils de années. Par conséquent, l'urée n'arrive plus à satisfaire à sa propre norme. En ravanche, il n'existe à l'heure actuele aucun autre agent de déverglaçage susceptible de la remplacer.

Un autre point demande une attention particulière; il s'agit de l'absorption de ces produits par les moteurs des aéronefs et qui fait problème en raison de la présence du sodium dans le NaFo. Le sodium, qui est aspiré dans la turbine à gaz, se combine au soufre contenu dans les gaz de combustion pour former du sulfate de sodium, Na_2SO_4, lequel a la propriété de ronger les superalliages. Il est à constater qu'aucun essai d'absorption par les moteurs n'a été effectué sur l'urée ou l'ACM. L'étude de la contamination de l'air d'aliminentation des turbines à gaz par differents produits chimiques figure parmi les travaux de recherche et de développement à consertir dans ce domaine. Pour des raisons de garantie de moteurs, les aéroports attendent que les fabricants de moteurs à turbine à gaz aient approuvé les produits chimiques utilisés sur les aéronefs, et à proximité, avant de les utiliser. Les deux motoristes, Pratt & Whitney Canada Inc. et General Electric, approuvent malgré eux les produits utilisés actuellement sur les chaussées aéronautiques.

- **Compatibilité avec les matériaux des chaussées aéronautiques**

Les résultats des recherches menées en milieu routier sur la compatibilité des agent de déverglaçage avec le béton et les barres d'armature peuvent être transposés au milieu aéroportuaire.

L'urée est l'agent de déverglaçage, qui induit le plus haut taux d'écaillage du béton, suivi du formiate de sodium, puis de l'ACM.

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Lors d'essais effectués sur les tabliers et les structures de nouveaux ponts, l'ACM et l'eau distillée ont obtenu le même taux de corrosion de l'acier, suivis du formiate de sodium. La propriété qu'aurait l'ACM de ralentir la corrosion lorsque utilisé sur du béton ou des barres d'armatures contaminés au NaCl n'a pas encore été vérifiée en milieu routier. Il reste également à déterminer que l'ACM aurait aussi cette propriété lorsque utilisé sur les mêmes matériaux, mais contaminés à l'urée. Aucun des documents de référence consultés ne faisait état d'une comparaison avec les propriétés corrosives de l'urée. Il reste donc à comparer l'action corrosive de l'urée sur les barres d'armature avec celle du NaFo et de l'ACM sur du béton neuf et du béton contaminé par l'urée.

- **Efficacité opérationnelle**

Les essais effectués en sites routiers urbains ou ruraux renseingnent sur l'efficacité relative des agent chimiques de déverglaçage envisageables. Toutefois, leurs résultats ne sont pas directement transporables puisque, dans les aéroports, on ne retrouve pas la circulation dense des voies urbaines et autoroutes, factuer qui aide à accélérer le déverglaçage. De plus, ces essais sur autoroutes n'ont pas évalué les propriétés antigivrantes des fondants chimiques; enfin, une équipe d'entretien d'autoroutes ne peut porter autant d'attention à un tronçon de route donné, qu'une équipe de déneigement aéroportuaire, aux chaussées aéronautiques. Toutes ces raisons font qu'il est indispensable d'effectuer des essais spéciaux sur chaussées aéronautiques.

Les seuls essais in situ effectués en milieu aéroportuaire - à Brunswick, dans l'État du Maine, en 1988, par la Federal Aviation Administration (FAA) des États-unis - ont été jugés des plus préliminaires et peu concluants. On travaille actuellement à l'élaboration d'un projet visant à effectuer, cet hiver, de nouveaux essais qui s'avérent plus que

nécessaires. Ces essais visent des abrasifs et des fondants chimiques utilisés comme agents de diverglaçage seulement. Or, il est également nécessaire d'inclure l'observation des propriétés antigivrantes des fondants chimiques. Ces essais d'antigivrage sont des besoins spécifiques au milieu aéroportuaire.

- **Effets sur l'Environment**

Les nombreaux travaux de recherche et de développement sur l'impact écologique de l'ACM en milieu routier semblent pouvoir s'appliquer en milieu aéroportuaire. Ces travaux comprennent des essais standard, décrits dans des documents de référence, comme le "Standard methods for the Examination of Water and Wastewater[1]", pour l'analyse de la toxicité de l'eau, l'étude du lessivage des sols et la conduite d'expériences sur parcelles expérimentales.

Le document de l'Université de Washington[2] comprend les expériences en laboratoire, de même que des expériences contrôlées sur le terrain qui illustrent l'évolution de l'ACM dans l'environnement, et ses effect sur celui-ci. Cependant, cette étude énumère aussi les points suivants qui restent à vérifier:

1. Les concentrations et les quantités d'ACM qui atteignent les eaux de surface réceptrices par la voie du ruissellement et la perte d'oxygène dissous qui en résulte.

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[1] Standard Methods for Examination of Water and Wastewater, 16e éd, American Public Health Association, 1985.

[2] HORNER, R.R., Environmental Monitoring & Evaluation of Calcium Magnesium Acetae (CMA). Université de Washington, avril 1988.

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2. La mobilisation de métaux traces induite dans les sols exposés et les concentrations de ces métaux dans les eaux d'implatation, souterraines et de ruissellement.

3. La mobilité de l'acétate dans les sols selon les taux d'application pratiqués et, plus spécialement, sa teneur dans les eaux souterraines, et ses effets sur celles-ci.

4. Les types de microbes qui se développent dans le sol en présence d'ACM.

5. La vitesse à laquelle les solides deviennent saturés de cations majeurs.

6. Les impacts du CMA sur le biota aquatique.

A l'heure actuelle, la Federal Highway Administration ne prévoit pas poursuivre les recherces environnementales dans ce domaine. Il est prévu que le "Strategic Highway Research Program" (SHRP) traite des questions en suspens dans son projet de recherche actuel intitulé "Evaluation of Procedures for De-icing Chemicals (H205)".

Même s'il a été possible d'identifier certains des effets du formiate de sodium, en prenant en considération les ressemblances et les différences de ce produit avec le chlorure de sodium, il s'agit d'un fondant chimique qui ne s'est ajouté que récemment à la gamme des agents de déverglaçage envisageables, et qui doit donc être évalué en fonction de ses effets sur l'environnement. L'urée doit aussi être soumise à ces essais afin de pouvoir effectuer une comparison directe.

- **Analyses coûts-avantages**

  Si certains des factuers pris en compte dans une analyse côuts-avantages en milieu routier (par exemple la compatibilité avec le béton et les barres d'armature, la corrosion de véhicules, les effets sur l'environnment) interviennent aussi en milieu aéroportuaire, il demeure que c'est à un degré bien different.

  En plus de cette différence dans "l'ordre de grandeur" de l'effet des parametrès-clés communs en question, l'analyse coûts-avantages en milieu aéroportuaire doit aussi prendre en considération d'autres variables comme:

  - les coûts des déroutements et des retards causés par la fermeture d'une piste, et

  - la détérioration des aéronefs.

  Les coûts des retards ont été traités dans des études antérieures (par exemple les demandes d'amélioration des systèmes d'atterrissage aux instruments sont basées sur une analyse coûts-avantages exhaustive effectuée par Transports Canada). Cependant, l'analyse coûts-avantages concernant l'entretien hivernal des chaussées aéronautiques ne tient pas compte des coûts associés aux retards.

  En résumé, les analyses coûts-avantages en milieu aéroportuaire sont à ce point differentes des études économiques sur les infrastructures routières qu'il y aurait lieu d'entreprendre pour chaque aéroport, une étude exhaustive spéecifique; Transports Canada pourrait ainsi décider en connaissance de cause dans chaque cas.

- **Prescriptions Techniques**

Il cerait essentiel que la SAE/FAA ou Transports Canada, mette au point une série complète d'essais normalisés permettant de caractériser tous les agents de déverglaçage chimiques solides envisagés pour les chaussées aéronautiques. Aux États-Unis, le SHRP finance un poject de recherche en ce sens s'appliquant au milieu routier (le project H-205, "Evaluation Procedures for De-icing Chemicals"); il est prévu qu'un grand nombre des procédures d'évaluation qui ressortiront de ce project, d'une durée de trois ans, pourront s'appliquer en milieu aéroportuaire. Les résultats du projet devraient être disponibles au début de l'année 1991. Certaines préoccupations, uniques au milieu aéroportuaire, mais importantes, devraient faire l'objet d'une recherche particulière et être ajoutées à un project comme le H-205; ce sont:

- les effects sur les matériaux de la cellule et du groupe propulseur des aéronefs, et

- les caractéristiques d'antigivrage des produits, par opposition à celles de déverglaçage.

Dans le domaine aéroportuaire, les États-Unis ont créé un comité chargé de remanier la série actuelle des "Aerospace Materials Specifications" (AMS 1426A pour les agents de déverglaçage liquides) et de redéfinir la spécification AMS 1730A (urée) afin d'y inclure tout fondant chimique solide. Les travaux dans ce domaine ont progressé lentement jusqu'à présent. Cependant, l'ébauche d'une nouvelle norme (J88BM) a été soumise au SAE et le comité semble maintenant agir plus rapidement que par le passé.

Les auteurs du présent rapport signalent qu'il existe très peu d'études comparant, en milieu routier, l'efficacité de l'urée à celle d'autres agents de déverglaçage envidageables pour les chaussées aéronautiques (la même remarque vaut pour les études en milieu aéroportuaire); aussi, les données comparatives sur l'efficacité de l'urée, de l'ACM et du formiate de sodium en milieu aéroportuaire sont-elles en majeure partie basées sur des extrapolations des résultats de recherches effectuées en milieu routier. Par conséquent, il est recommandé qu'une recherche soit effectuée sur les lacunes identifiées avant que Transports Canada n'autorise l'utilisation de l'ACM et du formiate de sodium.

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I INTRODUCTION

In April, 1988 the Transportation Development Centre of Transport Canada contracted SYPHER:MUELLER International Inc., to investigate calcium magnesium acetate (CMA) for use as a de-icer at Transport Canada airports. This report compares CMA to urea, the chemical de-icer presently used on Transport Canada airport runways. The scope of this report was expanded to include yet another alternative de-icer which has gained recent interest for use on roadways: sodium formate (NaFo).

Sections II, III, IV and V of this report summarize the present state-of-knowledge of de-icing/anti-icing chemicals for the airport environment, more specifically, CMA, NaFo and urea. Section VI highlights the gaps in the research and development of the alternative chemicals (CMA and NaFo) which require attention before any wide-spread airport use can be expected.

A. BACKGROUND

To sustain year-round flight operations at Canadian airports, Transport Canada uses large quantities of de-icing and anti-icing chemicals. The compound used for the prevention or removal of ice on airfield pavements is urea.

Urea is the only anti-icing and de-icing chemical that has been approved as being suitable for such purpose on Canadian airport runways when evaluated on the basis of:

- effectiveness
- non corrosive and innocuous effects on aircraft
- availability and ease of application
- cost practicality

No other chemical tested to date possesses the foregoing combination of favorable characteristics. However, urea does present some problems. Urea does not pass the current test requirements for hydrogen embrittlement. Also, agricultural grade urea generally contains significant free ammonia and does not pass the cadmium plate test requirement.

Furthermore, urea imposes some environmental problems. Urea used on runways results in several soluble forms of nitrogen becoming available for solution in snowmelt waters, soil moisture, runoff waters and perhaps in ground waters. Although quantification of the amounts of water-soluble nitrogen as a result of urea application on runways is difficult, site specific investigations have confirmed adverse environmental effects, due to nitrogen loading of streams and lakes in their vicinities. As a result of urea's environmental effects, it has been recommended that airport maintenance include precautionary steps such as:

- regular spreading or double snow blowing of snow containing urea over a broader area (i.e., distances up to 100m from the runway)

- control of grass areas adjacent to runways (100m) to maximize growth in order that its harvesting can remove nitrogen from the nitrogen collecting area

A program of soil and runoff water monitoring has been recommended in order to flag high and potentially damaging nitrogen loadings. If these conditions are detected, the removal of urea-laden snow should be considered in combination with an appropriate pollution control technique such as land application or trickle filtering the runoff through a wastewater treatment plant.

Recent concern over the impact of urea on the surrounding environment, when used as a de-icer, has resulted in the search for a de-icer which has a less severe environmental impact. Increasing interest in recent years (e.g., the US Federal Highway Administration, several US state departments of transportation, the Ontario Ministry of Transportation and Communications and others) in alternatives to conventional road salt for snow and ice control on highways and city streets has focused primarily on calcium magnesium acetate (CMA).

Recent tests [40] show CMA to have no significant corrosion on steel, zinc or aluminum. In addition, laboratory test results [9] presented at the Transportation Research Board (TRB) annual meeting (January 13, 1988) indicate that asphalts,

plastics, ceramics, rubber compounds and sealers were unaffected by CMA. The same tests concluded that CMA minimally affected portland cement concrete through minor scaling. Tests done by Chevron Health Center [8] conclude that CMA is essentially non-toxic.

With respect to environmental impact, the biochemical oxygen demand (BOD) is an indication of the effect of water pollutants. Both the calcium and magnesium acetates are organic and are slowly broken down during the winter months reducing any potential biochemical oxygen demand stress. Urea requires 4.5 times the theoretical biochemical oxygen demand of CMA. The magnesium ion does appear to displace the iron, sodium, aluminum and solid forms of the potassium ion during high CMA loadings [12]. And lastly, field tests of CMA by SYPHER:MUELLER [17] on City of Ottawa streets indicate that on average 1.6 times the amount of CMA is required to produce the same melting action of road salt. These data suggest that the same amount of CMA as urea would be required to attain equivalent melting action. However, the differences in experimental design and purpose (eg. anti-icing versus de-icing) and the continual plowing and sweeping experienced in an airport environment should reduce this 1.6 application factor. Airport field tests would verify this hypothesis.

Recent interest in another potential chemical substitute for road salt has identified sodium formate (NaFo). While CMA has undergone and is currently undergoing evaluation in a number of areas, and its use is well documented, information associated with the use of NaFo as a de-icer is limited. Preliminary work done for highway research with NaFo indicates that the de-icer is less corrosive than road salt and less damaging to concrete than salt and urea. Most of the environmental impacts predicted for NaFo are based on its similarities/differences with other de-icers, primarily NaCl. These findings need to be verified.

In response to the potential environmental impact of urea, in combination with the recent popularity of potential alternative de-icers for roads, Transport Canada has identified CMA and NaFo as possible alternatives to urea as a snow and ice control agent on Transport Canada airport runways. However, before CMA and NaFo can be used as a substitute for urea in airport snow and ice control programs, CMA and NaFo must be evaluated and confirmed as environmentally sound and cost-effective in airport surroundings.

B. OBJECTIVES

The objectives of this study are to prepare a state-of-the-art review of previous, current and future Calcium Magnesium Acetate (CMA) and Sodium Formate (NaFo) research and to document the current status in relation to the following six subject areas:

1. Technical specifications for use as a de-icer on the airside pavements of Transport Canada airports. Standard test procedures to determine compliance with the technical specification(s) shall also be specified.

2. The compatibility of CMA and NaFo mixtures with various aircraft materials using standard laboratory test methods.

3. The environmental impact and the occupational health and safety considerations of the use of CMA and NaFo at Transport Canada airports. A comparison with urea shall be made.

4. The impact of the CMA and NaFo mixture(s) on the integrity of concrete pavements including the pavement joint sealing materials. A comparison with urea shall be made.

5. A field test evaluation plan against which the ice and snow melting characteristics of the CMA and NaFo mixture(s) may be compared with urea.

6. A cost/benefit analysis comparing the CMA and NaFo mixture(s) vs urea.

The state-of-the-art review identified areas where more research and data is required.

Based on this review, detailed Terms of Reference addressing the above six program objectives were prepared. The Terms of Reference will permit the determination of the economical and technical feasibility of utilizing CMA and NaFo as a runway de-icing chemical at Transport Canada airports.

II UREA

In order to support the objectives of this study, the material gathered on each de-icer was sub-divided into by the specified six subject areas:

- technical specifications
- aircraft materials compatibility
- environmental impact
- airport runway materials compatibility
- field trials, and
- cost/benefit analysis.

A. TECHNICAL SPECIFICATIONS

The working document used by airport operations at Transport Canada airports is titled "Manual of Snow Removal and Ice Control, AK-72-40-000, April 1983".(1) The Material Requirements section (also shown in Appendix A) of this document that defines the Transport Canada specification (ICCS-U Appendix B) and properties the urea must adhere to in order to qualify for use on airport runways. As stated in these guidelines:

(i) Urea is approved for use in Canada on aircraft movement surfaces for the purpose of control of ice and compacted snow. The most suitable form of urea is granular or pellet. The particles are spherical and uniform in size and fall between the No. 6 and 20 Tyler sieve sizes. The grains may be coated with clay or mineral oil to prevent caking and bridging. It is free-flowing and can be satisfactorily applied with conventional sanding equipment. Because of appreciable material cost, equipment calibration and application rate should be precisely controlled.

(ii) Urea is effective in preventing the formation of ice and de-icing down to $-4^{o}C$ (for all practical purposes the pavement temperature). Its density is about 750 kg/m^3, or approximately half that of sand, and is not noticeably displaced by moderate wind after application.

(iii) Urea is non-toxic (as stored to humans) and may be stored in a building (heated or unheated)in its original sealed waterproof bags for a number of years without deterioration. Urea may also be stored in bulk inside a building.

The U.S. airport operators also use a specification written specifically for urea to assure them that the urea they buy is compatible for use on airports. This document is the Aerospace Material Specification (AMS) 1730A (shown in Appendix C). A specification has been written for a generic solid runway de-icer/anti-icer and is currently before the SAE committee in a draft format. However, a specification for a generic solid runway de-icer/anti-icer has not been accepted as of yet.

B. AIRCRAFT MATERIALS COMPATIBILITY

More than two decades ago, Transport Canada, the Department of Public Works Laboratory, the Department of National Defence, Air Canada Maintenance Engineering Materials and Process Laboratory (Air Canada base at Dorval), Douglas Aircraft Materials and Process Laboratory, and the Rolls-Royce Derby Laboratory in England performed cooperative investigations into the use of chemicals for the purpose of runway de-icing/anti-icing. As a result of the testing, it was determined that urea did not corrode aircraft parts, including aluminium, nor stain paints, and did not affect the plastic of aircraft windows [2]. Canada pioneered the use on a large scale of granular form urea as a runway de-icer/anti-icer. The Canadian experience and knowledge were made available to the world community through the International Air Transport Association (IATA) and the International Civil Aviation Organization (ICAO).

The introduction of non-corrosive and/or environmentally benign de-icing chemicals has triggered a battery of tests for alternative chemicals to meet before their actual use on airport runways. Urea has never been evaluated under the scrutiny by which researchers and organizations are implementing and interpreting tests for the new alternatives. One laboratory active in the testing of alternative de-icers [7] indicated

that even urea has a hydrogen embrittlement problem when tested for compliance to AMS 1730A (the specification for the urea runway de-icer/anti-icer). Most tests are the same in both the liquid (1426A) and urea (1730A) Aerospace Material Specifications.

C. ENVIRONMENTAL IMPACT

The chemical transformation of urea to ammonia will readily occur as long as urease-active microorganisms are present. This hydrolytic conversion can take anywhere from hours to days depending on temperature, pH, cation-exchange capacity, organic carbon and total nitrogen present and other factors. Since runoff generally flows over land or percolates through soil prior to reaching a drainage channel, any urea present will probably be transformed to ammonia in the process. If any urea remains in the runoff upon reaching a water course, it will ultimately be transformed to ammonia by urease-active organisms present in the sediment and/or suspended matter.

While urea itself exhibits minimal toxicity to aquatic life, its hydrolysis product - ammonia is highly toxic. Generally, urea concentrations have to exceed several thousand milligrams per liter before significant biological effects are evident. However, ammonia is toxic to fish at levels much less than 1 mg/L. Higher pH and temperature, which favour the formation of the un-ionized NH_3 ammonia specie, would be expected to increase toxicity.

After urea hydrolysis to ammonia, further biochemical reactions take place which utilize dissolved oxygen in the water. Certain bacteria can oxidize ammonia to nitrite (NO_2-), then nitrate (NO_3-). Nitrification could have a significant effect upon the oxygen balance of a receiving water. This may cause the dissolved oxygen content of the stream to drop below the level necessary to sustain the life of aerobic organisms. The situation is especially critical during conditions of high temperature and low flow, when the dissolved oxygen content of most streams is initially low, and the hydrolysis of urea occurs at an increased rate. However, in reality, this is unlikely to happen as temperatures during winter and spring months remain low.

The introduction of urea and its associated nitrogenous degradation products into surface waters can result in excessive algal growth. (This is not surprising since urea is frequently used in plant fertilizers.) This phenomenon will occur if nitrogen is the only limiting nutrient in the aquatic system, which often is the case. Algal blooms can create a number of problems, including tastes and odors in drinking water and fish kills associated with algal toxins and/or oxygen depletion. The continued nourishment of a body of water with excessive amounts of its limiting nutrient will result in an accelerated aging process. This is caused by the expired algal biomass and other organic matter which settles to the bottom and decays, gradually filling up the lake. The end result is a swamp, and eventually dry or boggy land. (3)

The widespread use of urea at Canadian airports took place about the same time that these environmental concerns rose in the public's awareness. In response, a series of site specific investigations at selected airports in Canada were initiated. Although results from each investigation were highly dependent on the site's local geography, general conclusions were drawn (2):

- there is evidence that use of urea on airport runways does indeed result in one or more of three dissolved forms of nitrogen being present in some runoff waters, some snowmelt waters, and in soil of the grassed areas bordering runways. Those nitrogen forms include: urea itself, ammonium (NH_4+); and nitrite plus nitrate (NO_2- plus NO_3-). Quantification of the amount of water soluble nitrogen, originating from urea applications on runways, in runoff waters and in soils near runways is generally very difficult.

- significant concentrations of dissolved nitrogen were apparent in runoff waters of several airports for limited periods of time.

- snowmelt and soil sample analyses confirm that little runway urea nitrogen is moved more than 30 m from runway margins by normal snow clearing operations on runways.

- the contributions of urea used at airports to nitrogen loadings of runoff waters leaving airports or to nitrogen loadings of lakes receiving such runoff waters have not been established. The nitrogen cycle reveals that a number of out comes (which are highly variable and hard to quantify) are probable for urea in

snowmelt and runway runoff waters. In addition, the quantification and significance of airport urea applications to nitrogen contents of streams in the vicinity of airports and to regional lake waters are very difficult to ascertain because there are so many other sources contributing to the nitrogen content of such waters.

- in general, there does not appear to be grounds for much concern about the contribution of urea use on airports to the nitrogen loadings of streams and lakes in their vicinities. However, the McAllister studies which this generality was based on is limited in scope and the samples collected were few. Some airports are situated in environmentally sensitive settings where drinking water could be impacted. Examples of such airports would be Dorval and Charlottetown. Dorval discharges stormwater upstream of the City of Lachine's water intake in Lac St. Louis. Charlottetown Airport is located on the recharge area of the city's drinking water wells.

- for reasons of safety and maintenance of reasonably reliable transportation services, use of urea as a de-icer and anti-icer on airport runways is justified even though there may be in some cases minor adverse environmental effects due to nitrogen loadings of waters.

Based on the significance of the conclusions the McAllister study [2] recommended:

- urea applications should always be at the lowest rates that will be effective.

- snow containing urea should be spread over distances of up to 100 m from runway margins whenever that is practical. Double or triple snow blowing should achieve such a distribution.

- the grassed areas adjacent to runways should be managed so as to maximize the growth of grass for distances up to 100 m from runways. Soil tests should be employed so as to obtain recommendations for any needed non-nitrogen containing fertilizers as may be advised to maximize grass growth.

- for distances up to 100 m from runways, grass growth should be harvested in such a manner as to maximize the total annual production and should be removed promptly after harvest. This practice will remove nitrogen from the nitrogen collecting area.

- urea-contaminated runoff water may be impounded for spring use on grassland areas some distance from runways, providing impoundments are on soils that are fairly impervious to water leaching.

- A program of soil and runoff water monitoring should be considered at each airport where urea is used on runways:

  - Soil monitoring should be planned and supervised by competent soil scientists. The nitrogen contents should be determined in a systematic manner in grassed areas receiving runway urea.

  - When monitoring of runoff waters or groundwaters is undertaken, careful planning, supervision, record keeping and execution will be essential to obtaining useful results. It will be essential to have competent environmental scientists capable of determining water flows and of designating analyses to be performed in charge of whatever, if any, water monitoring is undertaken.

  - If high and potentially important nitrogen loadings are found in airport runoff waters, the practicality of removal processing (on a seasonal basis) should be considered.

D. RUNWAY MATERIALS COMPATIBILITY

The same cooperative work effort involving those companies listed in the aircraft materials compatibility section conducted investigations into concrete spalling. They found that urea did have a scaling effect on new concrete.

These findings were supported in a recent study conducted by Domtar Inc., Canada [4] where a large number of concrete blocks were prepared by Canada Cement Lafarge in accordance with ASTM C672-84. The test basically consisted of ponding various solutions on top of the concrete slabs which were then subjected to freeze/thaw (f/t) cycles. At the end of every 5 f/t cycles, the de-icing materials were poured through a filter, the material that broke free was collected, rinsed and dried and weighed as a measure of the damage. Test concentration for each de-icer chemical was set at 4% solutions (NaCl, urea, $CaCl_2$, CMA and NaFo). Each point corresponds to the average value given by three identical specimens. The degree of spalling without abrasion caused by each de-icer is shown in Figure II-1. The relative large damage caused by urea is quite evident.

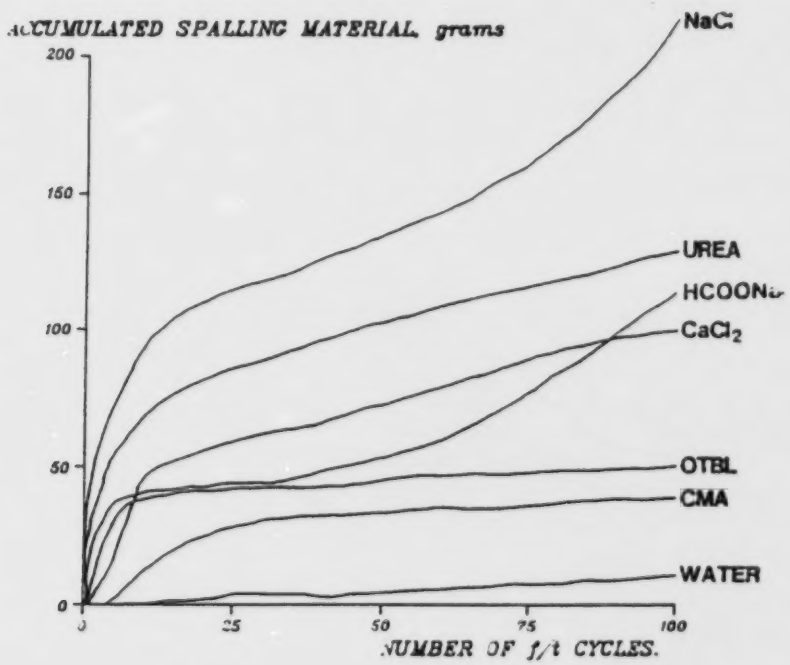

Figure II-1. **Air entrained concrete spalling by various de-icer solutions in the ASTM test. Concentration of all solutions was 4% [4]. (No abrasion)**

E. OPERATIONAL EFFECTIVENESS

Urea has been in use at airports as a runway de-icer/anti-icer for 30 years. As a result, the information base on the effectiveness of urea and urea related damages to the environment is well documented.

Urea comes in a pelletized (shotted or prilled) form and with a satisfactory anti-caking coating. Chemically, urea is a compound. In practice, however, commercial variations are available. Despite what is considered to be a restrictive working temperature range, urea is quite effective in preventing the formation of ice and compacted snow which almost always occurs above the eutectic temperature of 11.3^{o}C (11.6^{o}F) for urea. This one point, however, makes it necessary for the airport operator to remove the urea brine by sweeping when the ambient temperature starts to fall below -10^{o}C (15^{o}F) or before the brine begins to refreeze.

Excellent results are obtained when using urea as an anti-icing agent whereas as a de-icer the results are comparatively marginal. Comparison shows that over six times as much urea is required to remove ice as to prevent its formation. This ratio increases as the ambient temperature decreases. The main point being that, during an anti-icing operation, an airport runway is open for a much greater amount of time than during a de-icing operation. The de-icing procedure would demand that the runway be closed due to insufficient surface friction.

This described behavior was well supported at the 1988 International Aviation Snow Symposium. A workshop session [20] on runway de-icers revealed the following points:

- solid urea is effective down to -2^{o}C (28^{o}F)
- liquid urea is effective down to -4^{o}C (24^{o}F)
- urea brine has to be removed before it re-freezes

- liquid urea is gaining in popularity (approximately 28% diluted) for its reduced equipment maintenance and material cost
- solid urea is preferred for porous runways; liquid is useless as it just flows through the pores
- urea is more effective on wet snow than dry snow
- liquid urea (or other liquids i.e., UCAR) in combination with wet sand is used on a number of airports.

Urea has not gained much support from those researching de-icing alternatives in the roadway environment. Field trials conducted by Minnesota Department of Transportation in 1984 (5) concluded that urea was not an alternative to salt in its present form for the following reasons:

- high eutectic point (-10^{O}C)
- slow reaction time
- large amounts of material needed (1.6 times the amount need by NaCl)
- large quantity blown off the road
- high cost

Separate field trials conducted by Washington State Department of Transportation in 1984 (6) included three de-icing chemicals in its highway test program; Urea, salt and CMA. Pertinent conclusions in relation to urea (and its comparison to CMA) are:

- CMA reacted more slowly than urea
- 400-600 lbs per lane mile of CMA did not provide the same results as 400-600 lbs per lane mile of urea. The CMA used for these trials was of a finer, dustier configuration than presently available from the only commercial source; Chevron.

Similar supportive findings are reported from Alaska where a no-salt policy has been in effect for several years. (19)

Although research done in the roadway environment is transferable to the airport runway environment there is a critical difference in the application of chemicals in these two environments. Airport operators recognize and strive for applying the chemicals in an anti-icing mode whereas it is far too optimistic for municipalities to adhere to such an anti-icing policy. Roadway chemicals have the primary function of de-icing whereas airport runway chemicals strive for anti-icing but must also deice when required.

F. COST/BENEFIT ANALYSIS

Several studies have been conducted analyzing the cost and benefits of using non-corrosive and/or environmentally benign chemical de-icing alternatives to salt in an urban/rural roadway environment. However, none to-date have looked at the costs and benefits of replacing urea with an alternative chemical in an airport environment.

When attempting to quantify direct and indirect costs and benefits for an airport environment a number of variables must be attempted to be quantified. Some variables are common with cost/benefit studies performed for the roadway environment such as:

- concrete/rebar damage
- vegetation and soil impact
- ground vehicle and service vehicle corrosion
- local water quality impact
- chemical de-icer/anti-icer costs and availability
- handling and storage

Unlike the information presented in the environmental impact sections or the airport runway compatibility sections, information from previous cost/benefit exercises performed for the road environment is not completely transferrable to the airport environment. Some variables that are unique to a cost/benefit analysis in an airport environment would be:

- airframe and engine damage or discolouration
- increased level-of-service at airports
- flight delay cost reduction (increased airport usability)
- reduced maintenance area (runways vs. municipal road network)
- reduced snow clearance times

In order to present the reader with an idea of the order of magnitude of costs and benefits associated with de-icing chemicals, estimates drawn from cost/benefit studies previously published for roads evaluation will be reviewed.

All indications are that the value to the public of a bare road far exceeds the costs. One study which assessed the value of reduced traffic accidents, lives saved as a result of adequate medical response time, energy savings from reduced gasoline demand, and economic benefits related to reduced lateness and absenteeism, concluded that bare roads show a benefit/cost ratio of 6.3/1 to 18.1/1 depending on assumptions [35]. Indeed fuel savings alone can be comparable in magnitude to the direct costs of salt use. In addition to the several economic studies which arrive at the conclusion that bare roads are cost-beneficial, there are the practical realities that almost every community which has attempted to avoid the use of de-icers, and to reduce the level of service provided, has terminated the experiments.

Four winter maintenance programs were observed in a study performed in 1983 for the Alaskan DOT: [34]

(i) present maintenance using NaCl, $CaCl_2$ and outdoor stock piled sand.

(ii) substitution of CMA (for NaCl) and urea (for $CaCl_2$) and outdoor stockpiled sand

(iii) use of NaCl and $CaCl_2$ with heated sand storage buildings

(iv) use of CMA and urea with heated sand storage buildings

Inclusion of costs to the public from damages to vehicles and bridge decks, totalling approximately $5,169,000 per year in the study area, drastically changes the picture for de-icing salts. These materials have traditionally been considered the cheapest means to effective winter road maintenance because of their low material costs. Calculation of damages related to the use of sodium and calcium chlorides provides the basis of utilization of alternatives with apparent higher direct costs but with reduced damaging effects. As shown by the Table II-1, the apparent costs utilized in the past are very misleading in terms of the total cost picture.

Table II-1. Cost Analysis Summary - Annual Costs (34)

	Program	Direct Cost($)	Indirect Cost($)	Total Cost($)
A.	Present Levels - NaCl, $CaCl^2$, Sand	710,000	5,168,000	5,878,000/yr
B.	Substitute Chemicals - CMA, Urea, Sand	2,437,000	0	2,437,000/yr
C.	Reduced Amounts of NaCl and $CaCl^2$, Heated Sand Storage Buildings	624,000	775,000	1,399,000/yr
D.	Reduced Amounts of Urea and CMA, Heated Sand Storage Buildings	362,000	0	372,000

Examination of this total picture has probably not occurred previously due to the nature of the indirect costs. The money for de-icing programs, road maintenance, and vehicle damage comes from different pockets or at least different departments. In reality, all the costs are borne by the public in the end. Because of funding methods for the affected government maintenance programs, changes to the status quo will require a policy decision at the political level. It would be very difficult for the local maintenance manager to justify increased direct expenses solely on the basis of alleviating cost to individual citizens in his maintenance area. The maintenance manager's recognized concerns are solely considered to be maintaining safe conditions on the roads at the lowest cost. What must be recognized is that the lowest cost to the public is not synonymous with the lowest maintenance and operations program costs.

The Alaskan study concluded that public education and awareness of the total costs of road salting will be a necessary prerequisite for major policy changes. An educated public will support policy changes to reduce their cost burden.

An earlier report issued in 1976 by the U.S. Environmental Protection Agency placed the total annual national cost of salt-related damage at a minimum of $3 billion dollars, or approximately 15 times the annual national cost for salt purchase and application. (35) The $3 billion dollar cost represents a national average and is lower than the cost incurred in specific areas of high salt usage. That report studied damage to water supplies and health, vegetation, highway structures, vehicles, and utilities. The cost breakdown is as follows:

	Total (in millions) US Dollars
Water Supplies and Health	$ 150
Vegetation	50
Highway Structures	500
Vehicles	2,000
Utilities	10
Salt Purchase and Application	200
Total	$ 2,910
Billion	

The highest damage costs were found to involve vehicles and bridges. While elements in these two categories can be replaced, the cost is borne by the public in either instance.

Variables of interest to a cost/benefit analysis for airports include;

- cost of urea - $275.00/ton (FOB Ottawa)

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- major airport urea usage -

Airport	Annual UREA use (1981-1984 mean) (Metric Tonnes)
Charlottetown	100
Dorval	600
Edmonton International	20
Gander International	248
Halifax International	322
Mirabel	700
Ottawa	100
Lester B. Pearson International	300
Quebec City	90
St. John's Newfoundland	270
Winnipeg International	100

- Present availability - Urea is widely used agricultural fertilizer with unlimited availability. (However, this urea of agricultural grade, will not pass the current hydrogen embrittlement requirement of AMS 1730A)

III CALCIUM MAGNESIUM ACETATE (CMA)

As with urea, the material gathered on the research, development and demonstration of CMA is segregated into the six subject areas of interest:

- technical specifications
- aircraft materials compatibility
- environmental impact
- airport runway materials compatibility
- field trials, and
- cost/benefit analysis.

A. TECHNICAL SPECIFICATIONS

In the United States, two Aerospace Material Specifications are in existence for materials that see runway exposure: AMS 1426 A (fluids) and AMS 1730 A (urea).

AMS 1426A is a battery of test procedures which evolved in an ad hoc manner from test procedures already in existence; mostly for the engine cleaner and solvents areas. A list of the tests which presently make up AMS 1426A is shown in Table III-1. As test procedures for runway de-icing grew, some tests were included (and proposed to be included) that were fundamentally designed for gas turbine engine cleaners and solvents and were not totally consistent with the application of runway de-icers. More specifically, should a liquid runway de-icer be subject to AMS 1426A at a relaxed concentration (i.e. 10%) relative to a gas turbine engine cleaner because its designed intention is not the same as a gas turbine engine cleaner? In reality, an engine's exposure to any significant concentration of a liquid runway chemical would be far less than an engine's exposure to a cleaning solvent. (7)

Although this shortcoming in the AMS 1426A has been identified, product brochures such as Union Carbide's UCAR or BASF'S Icebreaker II identify compliance to AMS 1426A in order to market their product and assure to airport operators in the United States that their product is airframe and engine compatible.

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Progress in the United States towards approval of a material specification for CMA* a solid runway de-icer is slow, partly because there are so many interested parties but with no one of them responsible. However, as pointed out in the Aircraft Maintenance Chemical and Materials Committee meeting in March 30, 1988, "It appears that a lot of work has to be done before a good draft (specification) can be written. There is (not circulated) correspondence indicating problem areas such as concentration to be tested for corrosion testing (splashing on aircraft). .....Before we go further it was felt necessary that a subcommittee should study this material..... Pending the recommendations of this subcommittee/study group this draft will be put on hold". Since this meeting a second draft for solid runway de-icing/anti-icing chemicals has been submitted and is before the subcommittee (Appendix G).

This subcommittee consists of members of the SAE, ATA and the FAA who will reassess the appropriateness of the present test procedures, recommend the pertinent test and develop new test procedures for a specification. This new AMS specification should be broadly written to apply to any solid runway/taxiway de-icing chemical in a manner similar to AMS 1426A which refers to any de-icing/anti-icing fluid for runways and taxiways.

The most recent Aircraft Maintenance Chemicals and Materials Committee Meeting was held on October 26, 1988 in New Orleans. The only progress made at this meeting in the area of a solid runway de-icing/anti-icing chemical technical specification was the appointment of a chairman for this subcommittee/study group. It is anticipated that the progress made by this subcommittee on a technical specification will be glacially slow as the committee members are all volunteers on a technical expert level. The committee lacks members at a political level which could implement the findings of the study group.

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* The draft referred to was one for MCA (or CMA) submitted to the SAE AMS committee by Dr. A.B. Gancy (See Appendix D)

Table III-1. SAE Aerospace Div. Aerospace Material Specification AMS-1426A

Standard	Procedure
Sandwich Corrosion Test	
Aluminum Alloys	ASTM F1110
Total Immersion Corrosion Test	ASTM F-483
Aluminum Alloys	AMS 4037
	AMS 4041
	AMS 4049
Magnesium Alloy	AMS 4376
Titanium Alloy	AMS 4911
Carbon Steel	ASTM A109
Low-Embrittling Cadmium Plate Test (Al Alloys AMS 4037 and 4049)	ASTM F111
Hydrogen Embrittlement	ASTM F-519
Effect on Transparent Plastics	
Type C Acrylic Plastics	ASTM F-484
Polycarbonate (MIL-P-83310)	ASTM F-484
Polysulfon (MIL-P-83310)	ASTM F-484
Effect on Painted Surfaces	ASTM F-502
Effect on Unpainted Surfaces	ASTM F-485
Rinsibility (with tap water)	ASM 1426A
Pavement Compatibility	
Scaling Resistance	ASTM C-672
Slipperiness (NBS meter)	
Wet Concrete	AMS 1426A
Dry Concrete	AMS 1426A
Wet Asphalt	AMS 1426A
Dry Asphalt	AMS 1426A

B. AIRCRAFT MATERIALS COMPATIBILITY

As previously discussed in the Technical Specifications section, no general specification or battery of accepted aircraft materials compatibility tests presently exists for solid runway de-icing/anti-icing chemicals. In order for the only company commercially producing CMA (Chevron Chemical Co.) to prove to airport operators that its product is compatible with the aircraft environment, Chevron has mixed 15%

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CMA test solutions and tested them against the stringent airframe manufacturers requirements for liquid runway chemicals (AMS 1426A). Scientific Material International Inc. (SMI) of Miami, Florida performed the applicable tests of AMS 1426A with the 15% ICE-B-GON^{R}(the CMA product name). SMI testing has shown that CMA does not corrode most airplane materials but it does leave a stain or discoloration on aluminium. The aluminium sandwich corrosion coupons were reported as non-conforming, with pitting as the problem. The appearance of the aluminum, after closer examination, was determined to be the result of a film rather than degradation. Furthermore, the principal investigator in-charge of these SMI tests believes the film itself may not be deposited at normal de-icing temperatures(8). Chevron has since modified its ICE-B-GON formula for runway use. This product (ICE-B-GON(C)) now passes this sandwich corrosion test.

A second concern with CMA is the amount of chloride impurities which ends up in the product. CMA is produced by reacting dolomite lime with acetic acid. It is the limestone which introduces the chlorides into the product and chlorides are prohibited from the airport runway environment. This chloride problem was identified for experimentally produced CMA only.

Transport Canada has also contracted its own independent aircraft materials compatibility tests of CMA (36). The Ontario Research Foundation performed the following tests:

- ARP 1512 - Corrosion of Aluminium Alloys by Aircraft Maintenance Chemicals - Sandwich Test
- ASTM F483 - Standard Method of Total Immersion Corrosion Test by Aircraft Maintenance Chemicals
- ARP 1511A - Corrosion of Low Embrittling Cadmium Plate by Aircraft Maintenance Chemicals
- ASTM F519 - Standard Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes by Aircraft Maintenance Chemicals

- ASTM F484 - Standard Method for Stress Crazing of Aircraft Plastics in Contact with Liquid or Semi-liquid Compounds

The CMA tested passed the following tests:

1. Sandwich Corrosion of 3 types of aluminium alloys.
2. Immersion Corrosion of 3 types of aluminium alloys, magnesium alloy, titanium alloy and carbon steel.
3. Effect on 3 types of transparent plastics.

The CMA tested failed the following tests:

1. Sandwich Corrosion of 7075-T6 Alclad aluminium alloy.
2. Low Embrittling Cadmium Plate test.
3. Hydrogen Embrittlement test.

The CMA tested for Transport Canada was obtained from Brian Chollar of the Federal Highway Administration and was of a 200 US ton experimental batch of CMA produced by RAD Chemicals.

Chevron also ran their commercial product through the MCA specification proposed to the Aircraft Maintenance Chemical and Materials Committee last March. Although the committee has decided not to accept this MCA specification, its results did support that ICE-B-GON^{R} did slightly darken and form residue on AMS 4045 aluminium alloy. The results of these tests are shown in Appendix E. As previously mentioned, ICE-B-GON (C) has been recently formulated for runway use and now conforms to the AMS 1426A requirements (see Appendix H).

As additional information, recent research done for the highway environment on corrosion is also presented. A study recently conducted for the US Department of Transportation Federal Highway Administration [9] found that asphalts, plastics, elastomers, ceramics, wood, sign sheetings and paints, rubber compound sealers and adhesives were unaffected or similarly affected by both NaCl and CMA.

Solutions of NaCl and CMA appeared to have no effect on the hardness properties of the automotive brake lining materials. However, automotive hydraulic brake line tubings exposed to solutions of NaCl exhibited greater weight losses due to corrosion and more rusting and deterioration, than the same specimens exposed to solutions of CMA. Automotive steels exposed to solutions of NaCl consistently exhibited greater weight losses due to corrosion than did those steels exposed to solutions of CMA.

All electrochemical tests in the D.E.Slick work [9] were immersion type tests conducted in a nitrogen environment which make these results of limited importance. In actual highway conditions automotive metals are in contact with air-saturated environments. For instance, in cases where no general corrosion was detected, the rate of corrosion would increase exponentially with the degree of aeration. The main concern in a real highway environment is the materials susceptibility to pitting and crevice corrosion. Pitting and crevice corrosion appeared more prevalent on specimens exposed to NaCl solutions than CMA solutions.

C. ENVIRONMENTAL IMPACT

Two major research efforts have documented the present state-of-knowledge on the environmental impact of CMA: one was conducted by the California Department of Transportation DOT [10] and the second was performed at the University of Washington[11].

The purpose of the California DOT study was to evaluate, by means of a literature search and a limited laboratory study, the impact of CMA on the environment. Only short term impacts were identified; long term impacts were beyond the scope of the study. The California DOT work included aquatic bioassays on fish, macroinvertebrates, zooplankaton, and phytoplankton, assessment of the effect of irrigation and foliar CMA applications to terrestrial plants; and an evaluation of CMA effects on soils. Conclusions are summarized as follows:

- the addition of calcium and magnesium to a water body could result in an increase of water hardness. However, this would not be expected to be significant unless a relatively large amount of CMA entered a water body.

- CMA is less toxic to rainbow trout and fathead minnows than NaCl, calcium acetate, or magnesium acetate. A continuously maintained 5,000 mg/l concentration of equimolar CMA slightly delayed hatching of rainbow trout but does not influence the number of eggs that hatch.

- waterflea bioassays indicate that the 96 hr LC_{50} for CMA and NaCl were 1421 and 4,500 mg/L, respectively.

- algae bioassays indicates that CMA, calcium acetate and magnesium acetate are more toxic to algae than NaCl. An estimated 50 mg/l or less of CMA is necessary to eliminate any deleterious effects of CMA on algae.

- when leached through soil, CMA resulted in some removal of iron, aluminum and selected nutrients from soils.

- NaCl is more injurious to plants than CMA with one exception , the Russian Olive.

- CMA's impact on public health and safety aspects of surface water quality ground water quality and air quality are unknown.

- the magnitude of CMA concentrations that result from roadway snow and ice control will be less environmentally damaging than NaCl.

The second and most recent CMA environmental research effort of the University of Washington supports all of the conclusions of the previous California DOT study. This report involved laboratory and controlled field plot experiments designed to determine CMA transport characteristics, and environmental fate and impacts on terrestrial and aquatic ecosystems. Additional findings include:

- modeling using data from existing literature predicted that typical CMA concentrations in spray and runoff from highways would be order of magnitude 10-100 mg/l, and typical annual mass loadings would be approximately 10 tons/linear mile (5.5 metric tons/km). The maximum concentration expected in any normal circumstances is 5000 ppm, with washoff of a large CMA application by an intense, small storm. Receiving waters would dilute this concentration.

- CMA did increase the permeability of soils by up to 20 times over controls, but the final hydraulic conductivity rate of approximately 10^{-5} cm/s is not believed to be a cause for any concern relative to CMA use or environmental impact. CMA did not affect the plasticity, insistence-density characteristics, unconfined shear on compression strength of medium-textured soils.

- most soils have capacities to immobilize years of calcium and magnesium applications in the amount expected from highways. Field evidence (appearance in shallow groundwater) confirmed laboratory tests findings on the tendency for some trace metal mobilization, but the trend was not as consistent or as strong as in the laboratory. The quantities released in these experiments would pose no environmental hazards, but it is unknown whether mobilization from heavy metal-contaminated in actual roadside soils would produce hazardous mobilization of these toxic metals.

- a large proportion of the CMA biodegradation occurred in the top 3 cm in field plot soils. Soil bacteria counts were temporarily elevated after CMA application. In water, the ultimate biochemical oxygen demand (BOD) was found to be about 75 percent of applied CMA concentration. The majority of this ultimate BOD was exerted within five days at 20^{o}C to 10 days at 10^{o}C, but not until 20 days at 2^{o}C. At the latter temperature it was estimated that 100 days would be required for full decomposition.

- the demonstration of retarded CMA decomposition in both soils and water at near freezing temperature indicates that, without warming, acetate would be present in both media for a period of weeks after being washed or sprayed from a highway. Oxygen demand would be exerted gradually under these conditions but much more rapidly at higher temperatures.

- oxygen depletion due to CMA addition to water was demonstrated in both the laboratory and the field ponds. CMA concentration of 100 mg/l (and higher) fully depleted oxygen within two days in BOD tests. Approximately 10 mg/l temporarily reduced saturated dissolved oxygen levels in field ponds by about half. This ability for relatively low CMA concentration to reduce dissolved oxygen in water is the leading potential environmental impact of concern identified by the research.

The findings of this study led to the development of guidelines intended to control the location and timing of CMA application to avoid the two concerns identified with the use of CMA:

i) potential impact on dissolved oxygen resources

ii) the mobilization of trace metals.

A study conducted for Transport Canada on the potential environmental effects of using CMA at Canadian airports [12] concluded that, with the current state-of-knowledge (May, 1986) that there could be an unacceptable environmental risk at 7 out of 11 airports studied. It is anticipated that with the results and guidelines of the University of Washington [11], this number would be reduced by an undetermined amount.

D. RUNWAY MATERIALS COMPATIBILITY

In contrast with the air-saturated airframe corrosion rate which increases exponentially with the degree of aeration, reinforced steel in runway concrete experiences a very low aeration environment. Studies conducted for highway research show that non-chloride de-icing chemicals cause some initial corrosion to rebar in this low aeration environment which essentially forms a protective barrier inhibiting any continued corrosion, whereas chlorides have the ability to continue to penetrate this initial corrosion barrier. Figure III-1 illustrates this corrosion rate concept. The CMA corrosion rate slightly decreases with time whereas the NaCl corrosion rate continues to increase with time. [13]

Recent research conducted by Michigan Department of Transportation [14] tested the effects of CMA and NaCl on all the metals anticipated in a highway environment. Two important findings included, i) CMA is 1/10 to 1/3 as corrosive as NaCl, and ii) CMA in solution causes uniform pitting and thus, smaller stress concentrations than NaCl.

Complementing research was done at the Turner-Fairbank Highway Research Center in Virginia for the Federal Highway Administration [15] (FHWA). These laboratory studies and an ASTM standard C876-80 established that reinforced black steel potentials greater than - 350 mV (with respect to a copper-copper sulfate reference electrode) indicate that there is a greater than 90 percent probability that corrosion is occurring in areas of the steel at that time.

Figures III-2 and III-3 show the potentials measured for the embedded black steel rebars of the CMA and salt-ponded slabs over the 4 year period of the test. The slab ponded with 3% CMA solution and the slab ponded with the 5% CMA solution showed electrical potentials of black steel rebar which varied between 0 to 60 mV. These potentials are not in the corrosive range.

The potentials of the slab ponded with the salt solution numerically increased from -100 mV to -280 mV in the first 3 months, and then to -580 mV in the next 3.5 years well within the corrosive range. After 4 years, the surface condition of the CMA-ponded slabs showed no signs of surface cracking. After 3 years, the salt-ponded slabs experienced concern cracking in areas directly over the rebars. With time the cracks became wider and rust stains appeared along the cracks.

Relative to NaCl solutions, CMA shows superior corrosion and concrete scaling properties. Nonetheless a direct comparison with urea in these areas still has to be performed. Direct comparisons with NaCl in corrosion tests such as this have enabled those interested in substituting NaCl with CMA in a roads environment to easily draw conclusions. However, until urea and CMA are tested against each other with accepted procedures, only indirect conclusions can be offered.

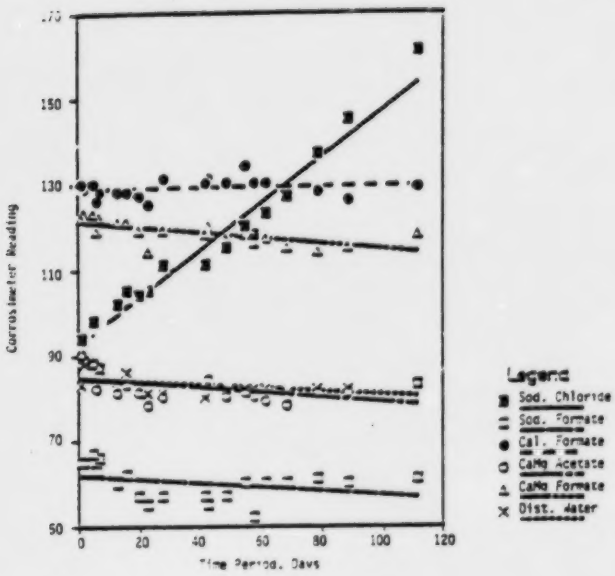

Figure III-1. Corrosivity of De-icer Solutions on Carbon Steel in Concrete (13)

a Solution concentration - 10% by weight in water

b rate of corrosion is indicated by the rate of change of the corrosimeter reading, 1 unit = 0.004 mil

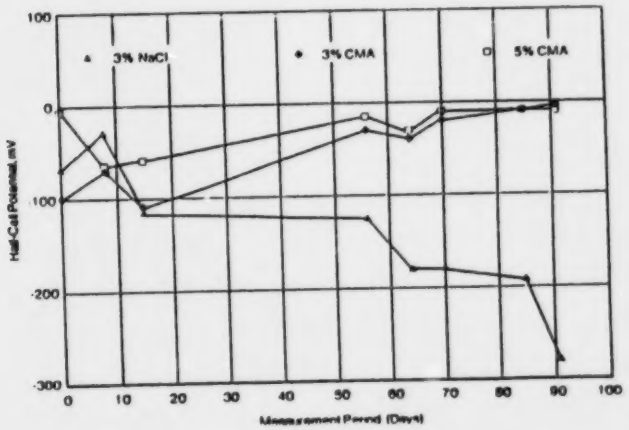

Figure III-2. Potentials of rebars in slabs ponded with salt and CMA; March - June 1982 (15)

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This FHWA report contradicts an earlier study conducted by Locke at the University of Oklahoma where it was found that "CMA will corrode exposed metals less than will sodium chloride, but there may be little difference in the corrosion of reinforcing steel when CMA is used [39]". Although the FHWA study and the University of Kansas study came to different conclusions on rebar corrosion, both concluded further testing is needed to specifically address the effect of CMA usage upon rebar in concrete previously contaminated by road salt [40]. With respect to the airport runway environment, this highlights the need to address the effect of CMA usage upon rebar in concrete previously contaminated by urea.

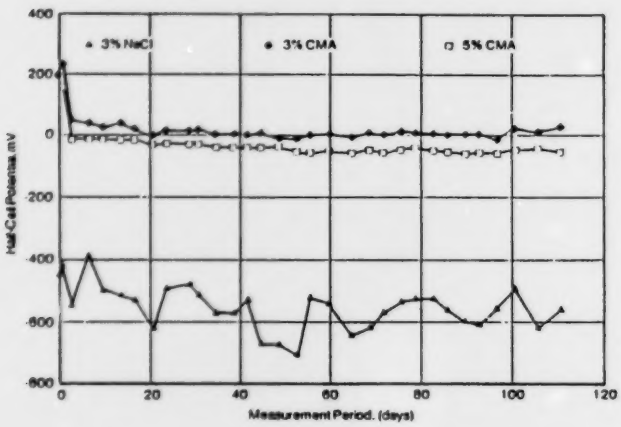

Figure III-3. Potentials of rebars in slabs ponded with salt and CMA; June to September 1986 [15]

E. OPERATIONAL EFFECTIVENESS

One set of alternative de-icer field trials has been conducted on an airport runway in Brunswick, Maine. These very preliminary tests took place in February 1988. The tests were specifically de-icing tests as opposed to anti-icing tests.

The test procedure involved covering a runway with 1/8" of ice and de-icing separate sections with various de-icing alternatives at various applications rates. The de-icing/anti-icing chemicals evaluated were urea, ICE-B-GON^{R} (CMA), and sodium formate, UCAR and ELE 286. Because of the low application rates tested, all de-icers had minimal effect in this de-icing mode at that ambient temperature (-7^{o}C or 14^{o}F) and the test was deemed to be inconclusive [16]. These runway field trails will be expanded this winter to include anti-icing and de-icing materials as well as other chemicals and abrasives. It is anticipated that common vehicle friction measuring devices will be employed as well as the 737 and 727 aircraft previously instrumented to measure aircraft braking performance. The FAA does not want to rely totally on field tests; consequently they will also be involved in laboratory testing and evaluations such as de-icer effects on bond strength. This research is being done in coordination with the Strategic Highway Research Program (SHRP).

A research project currently being conducted at the U.S. Navy's David Taylor Research Centre in Maryland is studying CMA and sodium formate (and others) in solution as potential liquid anti-icers for marine vessel use (e.g. aircraft carriers). Glycol based products result in a surface which is too slippery and unacceptable. As several commercially available products are being evaluated and the competitive nature of the project, no interim results have been made available[20].

In contrast with the limited field trails that have been performed for the aviation industry, numerous field tests have been conducted for the highway environment. The two most recent evaluations were of CMA vs NaCl in an urban environment [17] and a high volume inter-city highway environment [18]. The urban de-icer field test sections were monitored with a digital decelerometer which measures braking trials forces in % g deceleration. The test results are shown in Figure III-5 for a low traffic volume road and a typical storm for temperatures within the range of 0^{o}C to -5^{o}C.

Figure III-4 illustrates that although CMA is effective it does lag in its speed of effect relative to salt and requires an application rate 1.6 times that of salt. Figure III-5 presents the same data in a form which highlights the percentage difference in performance between CMA and NaCl through the storm duration.

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The study conducted by the Ontario Ministry of Transportation [18] found that with higher traffic volumes CMA performed comparable to NaCl. Although not a factor in the urban field trails the MTO study highlighted the ability of CMA to form a sticky brine on the road surface and possess a residual debonding effect throughout a snowstorm and even from one storm to the next.

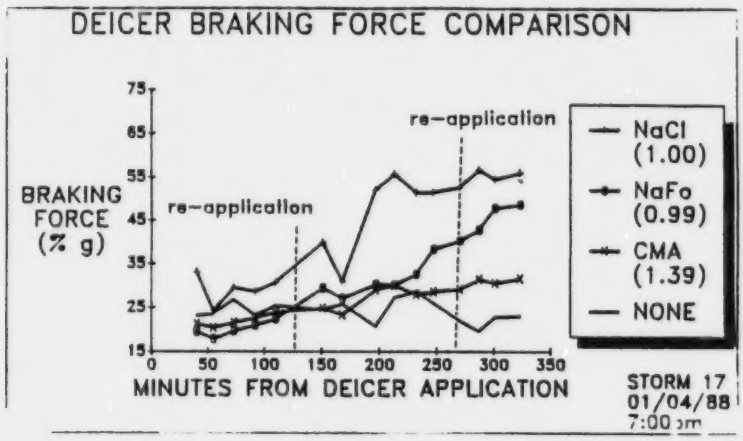

Figure III-4. De-icer Braking Performance: $0^{0}C$ to $-5^{0}C$ [17]

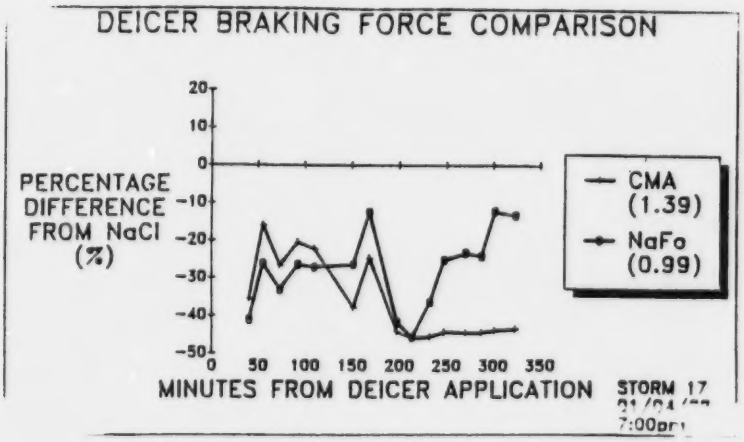

Figure III-5. Percentage Difference in De-icer Braking Performance vs NaCl: $0^{0}C$ to $-5^{0}C$ [17]

Another significant point in considering CMA for use as a de-icer is the fact that CMA requires approximately 1.6 times the weight of NaCl to produce a comparable de-icing effect. The City of Ottawa winter long field trials on a low traffic volume road verified this previously published application factor. This application factor may be reduced for the anti-icing role anticipated at airports.

In summary, the research conducted on CMA in the highway environment supports the fact that CMA seems to be more of a de-bonding chemical than a de-icing chemical. CMA requires a mechanism for snow removal which could either be a plow blade or high traffic volumes to push the snow to the road sides. Also, CMA appears to be reasonably effective when applied at the pavement/snow interface as an anti-icer. When applied on top of a snow pack, CMA requires substantially more time to react than NaCl. These findings seem to support a move to use CMA at airports (barring any materials compatibility or environmental problems) as airports strive to use chemical the majority of the time in an anti-icing mode.

F. COST/BENEFIT ANALYSIS

Discussion of previous benefit/cost exercises and the relevant cost and benefit centers applicable to alternative non-corrosive and environmentally benign de-icing chemicals is contained in the cost/benefit analysis section of urea. The most recent effort analyzing the benefits and costs of CMA was conducted for the roadway environment by the Ministry of Transportation of Ontario [37]. The findings are outlined for the province of Ontario and are as follows:

- the cost of CMA, anticipated by an expert group, was so high that the reduction in the five categories of environmental damage, namely vehicle corrosion, bridge deck deterioration, groundwater contamination, vegetation damage and damage to private property were not enough to offset material costs

- the most dominant components of the costs were, i) the cost of CMA and, ii) the vehicle corrosion costs

- the range of break-even costs for CMA was $343 to $481 per tonne

- if Ontario were to switch completely from salt to CMA the per capita cost would be just under $190 per year

- the benefit/cost ratio of a CMA de-icing program was calculated to be 0.8

Similar results were uncovered by a study performed for the City of Ottawa [38]. The additional cost of switching totally to CMA per household in the City of Ottawa was estimated to be $342 per year. This is based on an actual purchase price of CMA from Chevron Chemical of $500 US per US ton which translates into $1200 Cdn per metric tonne once shipping and duty are included. The resultant benefit/cost ratio was 0.88 for a CMA de-icing program. Only vehicle corrosion, bridge deck damage and parking garage damage were quantified as costs.

For comparison purposes, variables of interest to a cost/benefit exercise include;

- cost of CMA - $1,200/tonne (FOB Ottawa)

- predicted major airport loadings -

Airport	**Annual CMA * use (metric tonnes)**
Charlottetown	100
Dorval	600
Edmonton International	20
Gander International	248
Halifax International	322
Mirabel	700
Ottawa	100
Lester B. Pearson International	300
Quebec City	90
St. John's Newfoundland	270
Winnipeg International	100

*based on a 1:1 application ratio with urea.

- Estimated Present availability - If demand for CMA over the next year rose to 100,000 - 150,00 US tons, Chevron could meet this demand with their present production facilities. Should demand for CMA exceed 150,000 tons, Chevron would: a) investigate bio-acetic acid production over synthetic acitic acid, and b) expand their CMA production facilities to meet this demand.

IV SODIUM FORMATE (NaFo.)

All material gathered on the research, development and demonstration of the de-icer NaFo, was sub-divided into the six subject areas stated in the objectives:

- technical specifications
- aircraft materials compatibility
- environmental impact
- airport runway materials compatibility
- field trails
- cost/benefit analysis.

A. TECHNICAL SPECIFICATIONS

Sodium formate is subject to the same lack of progress as an AMS solid runway de-icer/anti-icer as is CMA. Currently, the only approved material specification for a solid runway de-icer/anti-icer is specific to urea (AMS 1730A). As interest in environmentally benign de-icing alternatives increases so does the need for an Aerospace Material Specification for a generic solid runway de-icer. Both Canada and the US presently support a specification for urea and no other alternative runway de-icer/anti-icer.

B. AIRCRAFT MATERIALS COMPATIBILITY

In acknowledgement of the fact that no recognized specification would officially endorse sodium formate as an accepted runway de-icing/anti-icing chemical, Celanese Chemical Company requisitioned Scientific Material International Inc. to conduct the AMS 1426A series of test procedures for liquid runway chemicals on a solution of NaFo. Results of these tests are shown in Appendix F.

Sodium formate, when diluted one part product to five parts water, passed all of the airframe materials compatibility tests except for the staining of specimens of AMS 4037 and AMS 4049 aluminium alloy in the sandwich corrosion test. Further evaluation of this staining by Hoechst Celanese showed that even tap water would cause staining of the aluminum coupons. Moreover, at ambient temperature (the sandwich corrosion test is conducted at 100°F 37.8 °C), no staining was observed with either tap water or sodium formate solution. Since aircraft would not be subject to de-icing chemicals at 37°C even in a heater hangar, the concern about staining may be a moot question. However, at the moment, this aluminum staining issue has not yet been resolved(20).

A second concern with the use of sodium formate lies in the ingestion of sodium into the gas turbine engine. Sulfidation is a common name for a type of hot corrosion which can affect turbine area components of gas turbine engines. It is caused by the condensation of an alkali metal salt, usually sodium sulfate, on the surface of the part. A cycle of chemical reactions then occurs which initially removes chromium from the protective oxide scale layer, and progresses to remove chromium from deeper and deeper in the component alloy, producing a thick, non-structural layer of scale. In advanced stages, the metal salt is trapped beneath the scale layer, and the rate of attack accelerates without the need for further contamination until structural failure occurs.

Sodium sulfate will form in the engine at operating temperature if sodium and sulfur compounds are both present. Most aviation turbine fuels contain traces of sulfur in sufficient amounts for sulfidation to occur if a source of sodium is present. The most common source of sodium is NaCl from seawater, but it can also be found in industrial atmospheric pollution and in volcanic discharges. In addition to the presence of sodium sulfate in the engine gas path, the temperature of the component must be in the range where condensation can occur. It is known that the amount of sodium present and the gas pressure can both affect this temperature range. Also, localized temperature gradients which occur during starting can greatly accelerate attack rates.

Erosion of turbine blades in turn leads to loss of power. A proven method of minimizing sulphidation is to deluge motoring washes using plain water This method of washing is used to remove salt deposits from the compressor and turbine section of the engine; however, light dirt deposits may also be removed. The washing medium is normal drinking water provided the minimum standards in the engine Maintenance Manual are met. Where ambient temperatures are below $2^{O}C$, ($36^{O}F$) it is required to add methanol to the water as per Maintenance Manual instructions. It is strongly recommended that this procedure be carried out when operating in a salt laden atmosphere. Washing mixture is injected into the compressor section and turbine section using washing nozzles.

When engine trend monitoring indicates a noticeable performance loss a washing mixture of approved chemical additives is substituted to remove deposits which cannot be removed using the desalination wash.

The water washing technique is particularly valuable in that it removes the contamination prior to starting the engine when accelerated attack can occur. Water used for washing must be free from contamination, although in most industrialized countries the local drinking water is acceptable. Otherwise, demineralized water should be used.

Wash frequency very much depends on the degree of contamination. For slight contamination, weekly washing is probably the minimum acceptable; for maritime areas daily or even before each flight may be necessary, although the engine must be reasonably cool before washing or the wash water may vaporize before entering the turbine area. The recommended wash frequency based on the operators estimate of the severity of the corrosion environment should be as follows:

Severe	-	daily (for constant flying in severe corrosion environment)
Moderate	-	weekly
Mild	-	monthly or 50 hours
Negligible	-	at regular performance recovery wash

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These recommendations do not take into account any future changes in levels of atmospheric contamination or effects of other possible sources of sulfidation such as contaminated fuel.

Figure IV-1 shows those areas in the United States which are known to have significant corrosion problems. This has been shown to have a close correlation with the normal areas of operation for PT6 engine operations who have reported sulfidation problems.

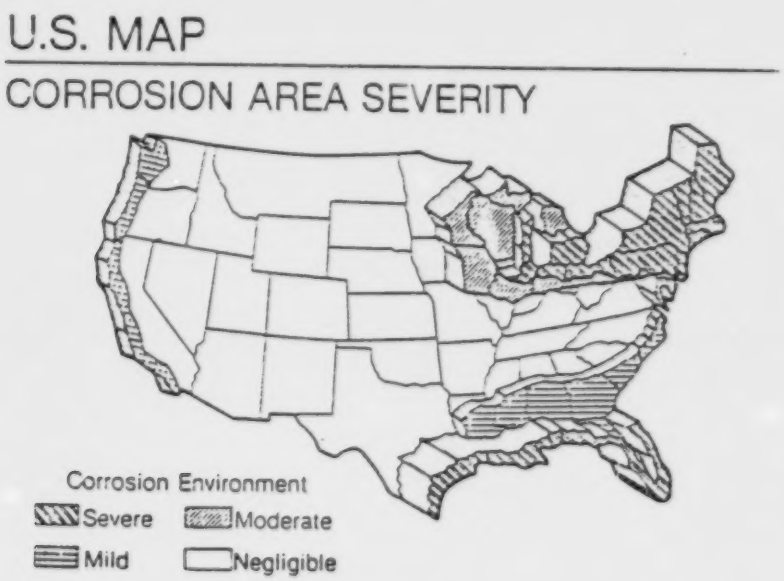

Figure IV-1. Areas of USA With Significant Corrosion Problems (25)

Information on corrosion problems on other areas of the world is not available in sufficient detail for meaningful maps to be produced. Nonetheless, the limited information available indicates that blade sulfidation is possible in costal areas and in any area where industrial pollution or "acid rain" is a known problem. (25)

As an example of the benefits of exercising water wash techniques, two hypothetical maritime operators would experience the following:

- no daily wash; 1000 hours of operation before an engine overall
- daily wash; 6000 hours of operation before an engine overall

Overhaul costs were estimated at approximately $30,000 for the PT-6 series of engines [23]. However, Air Canada, due to the variability of the service of any one plane, does not perform any of these desalination washes. Air Canada performs what is called a "B check" every 100 to 200 hours of operation depending on the aircraft which is an in-hanger thorough airframe check. It would be painless to incorporate these washes into their routine maintenance at this point.

Even though the problem of sulphidation is well documented, what is still unknown is the degree to which sodium formate when used as a de-icer/anti-icer would contribute to this problem. Airport operations strive for anti-icing and bare pavement using sweepers, plows, and blowers on the main runway(s), taxiways(s) and apron. In this case, one would think the engine would see very minimal de-icer exposure. However, due to snow removal resource limitation and increasing itinerant traffic levels, runways and taxiways can experience a snow accumulation and must be de-iced. Therefore, planes would be landing and applying reverse thrusters on NaFo laden wet snow. Based on a duty-cycle of approximately 100 hours between maintenance B-checks and the fact that the majority of this 100 hours of service would be in the air and an estimated number of landings that would actually take place in a de-icer laden runway, one would think that sodium formate exposure levels would be minimal.

The Structures and Materials Laboratory at the National Research Council (NRC) in Ottawa is presently conducting tests on a gas turbine engine burner rig to determine the effects of salt saturated air flows on various turbine blade protective coatings. Contaminating the air flow with NaFo, CMA or urea are possible tests which would quantify the potential damage. Preliminary estimates on the cost of such tests resulted in a quote for 200 hours of engine exposure from NRC and 500 hours of engine exposure for General Electric. The difference in the duration of de-icer/engine exposure in the proposed test approaches reiterates the fact that little is known in this de-icer ingestion area.

C. ENVIRONMENTAL IMPACT

In general, information associated with the use of sodium formate as a de-icer is very limited. Due to the uniqueness of the concept, very few data are available. As a result, most of the impacts identified in this section are based on the similarities/differences of sodium formate with other de-icers, primarily sodium chloride or salt. The information base on salt-related damages to the environment is very extensive and well documented. Several excellent reviews on the environmental, health and safety effects of using sodium chloride as a road de-icer have been completed. (24,25,26,27)

Sodium chloride is an excellent substance for removing snow and ice. It offers a reliable, convenient, and effective mechanism for de-icing. It is also inexpensive which explains its extensive use throughout Canada and the United States. However, salt being a chloride de-icer has been banned from use on airport runways and the large scale use of sodium chloride on roadways has been accompanied by adverse effects on the environment. For example, salt has been observed to upset the natural ecological balance. Examples of rusted bridges, bridge decks, and vehicles are common. In addition, damage to plant vegetation and contamination of water supplies have also been reported.

Salt damage to the environment results from complex processes. Not all the processes by which damage occurs are known, nor is the exact relationship between salt use and damage well understood. In addition, the effects of salt in nature are often cumulative and depend on many factors including precipitation patterns, amount of salt applied, weather conditions, and topography. Similar considerations may apply during sodium formate's use as a runway de-icer.

The contamination of water supplies is possibly the most serious damage that may result from the use of sodium formate. Sodium formate percolating down through the soil can enter groundwater supplies. It can also enter surface supplies as direct runoff. In general, shallow wells and small ponds near the runway are most susceptible to contamination by the de-icing sodium formate runoff. In comparison, pollution of well water usually is not due to groundwater contamination. Instead, the contamination results from intrusion into the wells of concentrated surface runoff water at drainage points.

The principle concern about sodium formate is that if it is allowed to run off into lakes, ponds, or wells, it could increase the sodium level of some water supplies. The role of sodium in all mammals including humans has been a contentious issue. In every mammal, sodium regulates the volume of blood and maintains the balance of fluids and pressure inside and outside the cells in the human body. It also plays an important role in nerve-impulse transmission, heart action, and the metabolism of carbohydrates and protein. Humans normally maintain a balance of sodium and other minerals at the proper concentration to achieve proper body function.

Although sodium is essential to the normal functioning of the human body, there has been concern about excessive sodium levels with respect to such conditions as hypertension or high blood pressure, renal and liver disease, and metabolic disorder [28,29]. Some of these conditions, especially high blood pressure, can be reduced by a diet severely restricted in sodium. The Canadian Heart Association has recommended a limit of 20 milligrams (mg) of sodium/liter in drinking water for patients whose diets are restricted to less than 1 gram (g) of sodium/day [24]. A safe and adequate sodium intake has been estimated at 1.1 to 3.3 g/day for adults. [29]

Another significant impact of increased sodium concentration in water is an increase in hardness ions. This increase occurs through an ion exchange process in which sodium cations from runoffs are absorbed by soil particles releasing calcium and magnesium ions. Higher levels (greater than 0.01 g/liter) of these ions are not considered as pollution but they do increase the soap neutralizing capacity of the water, and calcium forms a scale on utensils and appliances.

Another potential impact of high sodium formate concentration in water is lake stratification [24,25]. The situation could occur as large quantifies of sodium formate in solution enter a lake with a tendency to flow directly to the bottom. As the de-icer concentration builds up, it would tend to interfere with the mixing of the lake in the spring and fall. This would lead to anoxic conditions in the lower lake strata, causing the hypolimnion to slowly lose its supply of oxygen, thus breaking the food chain by killing the organisms and fish at the bottom of the lake [24,25]. Although not a common problem with salt, the potential of sodium formate to cause lake stratification needs to be evaluated.

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To date, no studies have been conducted to assess plant and vegetation damage from sodium formate's use as a de-icer. However, comprehensive assessments have been completed with salt. These assessments indicate that salt is often the prime factor leading to death of vegetation. These studies were based on soil samples and analyses of sodium and chloride contents in leaf and twig samples. One study clearly demonstrated the effect of salt by comparing tree damage on salted and unsalted roads in the same location [27].

In general, experiments and empirical studies with road salt have demonstrated that many trees used for roadside planting in the snowbelt are sensitive to increased sodium concentrations in the soil and that there is a direct link between the deterioration or death of roadside vegetation and de-icer application. The de-icer directly interferes with the chemical processes by which plants absorb nutrition and affects the osmotic balance, thus, inhibiting the water intake of plants. It may also replace vital nutrients.

The usual sequence of events in salt damage in plants is increasing sodium and chloride concentration in plant tissue, reduced growth, falling leaves, dropping twigs, dying limbs, and death. The degree of harm to vegetation depends upon the amount of salt, type of soil, amount of precipitation, and plant species. The use of sodium formate precludes it from the plant and vegetation damage associated with chloride ion. This fact would reduce the environmental impact of NaFo somewhat. However, the sodium ion is still present. Other factors such as automobile exhaust emissions, mechanical injury to roots during construction, and changes in soil moisture levels during paving also contribute to roadside plant and vegetation damage.

In addition to these direct effects, sodium in the soil may also result in a rapid deterioration of the soil itself. Several studies have indicated that when monovalent cations, such a sodium , occupy more than 15% of the total cation exchange capacity of the soil, soil structure begins to deteriorate [30,31]. Such breakdown results in decreased permeability and water-holding capacity of the soil. As a result, the soil becomes low in nutrients, and little, if any, vegetation can grow in it. In some cases, this in turn has led to severe erosion and the eventual clogging of drain sewers.

Since the cation species of both de-icers, sodium formate and salt, is the same (i.e. sodium), it is possible that the same types of plant and vegetation damage that occur due to the sodium in salt may occur with sodium formate. The extent of such damages, however, may be slightly reduced because sodium formate contains less sodium (33.8% by weight) than sodium chloride (39.3%) by weight). In other words, sodium formate will not alleviate potential problems from sodium ion contamination. In fact, the effect of Na^{+} on soil structure is entirely reversible. Addition of Mg^{+2} and/or Ca^{+2} to the soil would quickly displace the retained Na^{+}. In the acid soils of the northeast, this is done routinely and easily by the addition of lime. The same could be done at airports in the spring along with normal ground maintenance. This would also reduce possible Na^{+} damage to vegetation. In general, damage to trees can be minimized and often prevented by the selection of correct plant and vegetation species and proper planting practices. Good road and highway design, including adequate drainage systems for highways and curbs and gutters to carry street runoff into storm sewers, can also substantially reduce de-icer's damaging effects. This is also applicable to the airport environment.

The potentially harmful effects of sodium formate on fish life depend on the oxygen supply in water, water temperature, length of exposure, rate of de-icer concentration increase, and the presence of other chemicals in the water. In general, the use of sodium formate as a de-icer is not expected to cause damage to aquatic life, although this remains to be verified by a large scale environmental study on sodium formate. The theoretical oxygen demand for NaFo was calculated to be 0.24 grams of O_2 per gram of NaFo as compared to 0.85 grams of O_2 per gram of CMA.

D. RUNWAY MATERIALS COMPATIBILITY

Little direct corrosion testing has been done on sodium formate. Preliminary testing of 10% (by weight) solutions of sodium formate, sodium chloride, calcium formate, calcium magnesium formate, calcium magnesium acetate, and distilled water (as control) with carbon steel tubing indicate that the only de-icer showing significant corrosion with cement-imbedded carbon steel is sodium chloride with a rate of corrosion of about 1 mil/year. Figure III-1 of the CMA section illustrates each chemicals relative corrosion performance on carbon steel over time.

To be acceptable for public use, an alternative de-icer must be compatible with concrete and not cause excessive deterioration or spalling. Initial experiments by the California Department of Transportation (DOT) with sodium formate showed that the de-icer caused excessive spalling of concrete, and for this reason, it was dropped as an alternative de-icer even though its ice melting characteristics were comparable to sodium chloride [32]. Similar results were initially observed with calcium magnesium acetate [31]. However, this adverse effect of calcium magnesium acetate on the integrity of concrete was traced to its application on uncured concrete. It was also minimized by adjusting the pH of the calcium magnesium acetate solution from the reaction of dolomitic lime and acetic acid to about 8-9 prior to isolating the calcium magnesium acetate product.

Following The California DOT study, Celanese Chemical Company repeatedly tried to verify sodium formate's tendency to cause spalling of concrete using methods and techniques similar to the original study. However, contrary to the California DOT conclusions, Celanese did not find any evidence of concrete damage from sodium formate. They postulated that the sodium formate used in the California study may have been contaminated with substances detrimental to concrete. For example, sulfate compounds, which are known to cause concrete damage, are sometimes found in commercial sodium formate [20].

Recently, Celanese Canada contracted Dr. Litvan of the National Research Council of Canada to validate their findings. Preliminary results indicate that NaFo did not cause worse spalling of concrete than samples exposed to solutions of sodium chloride and most concrete samples experienced a lesser degree of concrete spalling [20]. Sodium formate has also not been observed to damage asphalt [33]. Figure II-1 contained in the Urea section seems to be the only publication to-date which allows a direct comparison of the concrete spalling properties of urea to those of NaFo and CMA [4]. As illustrated, NaFo shows slightly less spalling tendencies than does urea; and CMA shows significantly less degradation.

E. OPERATIONAL EFFECTIVENESS

As with CMA, NaFo was included in the brief airport runway field trails in Brunswick, Maine. Unfortunately, due to the nature of the test (de-icing on 1/8 " solid ice vs. anti-icing at the beginning of a snow) the findings were inconclusive. A more extensive set of runway field trails with instrumented aircraft as well as conventional vehicle runway friction measuring devices will take place this winter under the direction of the FAA.

Drawing on field trial work conducted in the roadway environment, NaFo was found to be somewhat comparable to the de-icing performance of salt but lagging in its speed of effect at the same application rate. When compared to CMA or urea this would translate into approximately a 40% reduction in the amount of chemicals used. Refer to Figures III-4 and III-5 in the CMA section to visually compare the performance of NaFo and CMA to road salt throughout a storm . A similar field test on a runway including urea would be necessary for comparing de-icer/anti-icer effectiveness.

F. COST/BENEFIT ANALYSIS

Discussion of relevant cost and benefit areas applicable to alternative non-corrosive and environmentally benign de-icing chemicals is contained in the cost/benefit analysis section on urea.

For comparison purposes, variable of interest to a cost/benefit exercise include;

- cost of NaFo - $480/tonne (FOB Ottawa)

- predicted major airport loadings. -

Airport	Annual NaFo use * (metric tonnes)
Charlottetown	63.
Dorval	375.
Edmonton International	13.
Gander International	155.
Halifax International	202.
Mirabel	438.
Ottawa	63.
Lester B. Pearson International	188.
Quebec City	57.
St. John's Newfoundland	169.
Winnipeg International	63.

*based on a 0.6:1 application ratio with urea.

- Estimated present availability - Approximately 75,000 tonnes of NaFo are produced each year in the United States and Canada as a by-product from the production of pentaerythritol and trimethylolpropane. Only about one-half of this production is recovered for sale and the rest is disposed of as waste. A small amount of NaFo is also produced by the reaction of CO and caustic soda for the production of sodium hydrosulfite. None is produced or used for de-icing. Should the market for NaFo exceed the by-product and limited on-purpose production rates available today, additional NaFo could be easily and inexpensively produced. For example, NaFo can be produced from the reaction of CO and caustic soda in a simple stirred tank ractor at moderate pressure (100-200 psi). Only water would have to be removed from the reaction product to produce a solid de-icer material. Steel mill off-gases rich in CO, for example, could be effectively used to produce low cost NaFo.

V SUMMARY COMPARISONS

In order to better understand the present state-of-knowledge that exists with all three chemicals and their relative performance and the various concerns in the six subject areas of concern a summary comparisons table (Table V-1) has been generated.

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Table V-1 RUNWAY DE-ICER/ANTI-ICER SUMMARY COMPARISIONS

	UREA	CMA	NaFo
TECHNICAL SPECIFICATIONS	. Cdn: ICCS-U . US: AMS 1730A	. Draft AMS J87BN for solid CMA put on hold by SAE committee inlieu of a generic tech spec	. None
AIRCARFT MATERIALS COMPATIBILTY	. hydrogen embrittlement problem . plays havoc in gas turbine engines	. staining aluminium in AMS 1426A . concern over chloride impurities of test batches of CMA; to be verified on commercial product	. staining aluminium in AMS 1426A sandwich corrosion . concern over sodium ingestion into gas turbine engine
ENVIRONMENTAL IMPACT	. water quality - significant oxygen demand - (7 times that of CMA) - eutrophication . soil structure - . plant and vegetation - increased growth . aquatic and animal - promotes algae growth . toxicity - highly toxic to fish	. water quality - water hardness - low concentration can deplete dissolved oxygen . soil structure - improves soil structure - mobilization of heavy trace metals . plant and vegetation - little effect . aquatic and animal - harmless . toxicity - moderate irritation effects	. water quality - small lake stratification - Na causes possible hypertension - water hardness . soil structure - reduces permeability . plant and vegetation - damage due to Na concentration in - plant tissue . aquatic and animal - little damage . toxicity - moderate irritation effects
RUNWAY MATERIALS COMPATIBILITY	. corrosion - no significant to rebar in new concrete . concrete - significant surface degradation	. corrosion - no significant to rebar in new concrete - impact to rebar in contaminated concrete . concrete - superficial scaling	. corrosion - no significant to rebar in concrete . concrete - marginal to significant surface degradation
FIELD TRIALS	. effective temp - (-4 deg C) . speed of effect - 1/2 hour . endurance - 1 hour . appl factor - 1.0 (relative to urea)	. effective temp - (-4 deg C) . speed of effect - 1 hour . endurance - 1-2 hour . appl factor - 1.0 (relative to urea)	. effective temp - (-4 deg C) . speed of effect - 1/4 hour . endurance - 1 hour . appl factor - 0.6 (relative to urea)
BENEFIT/COST	. cost/tonne - $ 275 . availability - unlimited	. cost/tonne - $ 1200 . availability - limited to acetic acid supplies	. cost/tonne - $ 480 . availability - by-product of petrochemical process

VI R & D GAPS ANALYSIS

To date, a significant amount of research and development funds have been allocated and spent in seeking an alternative to road salt for roadway snow and ice control. Of this research, a significant portion has been involved in direct comparisons of candidate alternatives with NaCl in those areas of interest to municipalities (i.e., auto corrosion, concrete compatibility, and environmental impact). As a result of high material cost, urea has been excluded from a large number of these research efforts conducted for the road environment. As a result, there is very little information directly comparing urea to any potential chemical alternative either for the road environment or potentially for the airport environment. At present, the relative performance of urea to CMA and NaFo can only be speculated. This is seen to affect all six subject areas addressed in the report.

The specific R & D gaps are summarized by the six general subject areas in Table VI-1, and are reviewed briefly below:

Technical Specification

A series of standard, comprehensive tests needs to be developed by the SAE/FAA that would qualify any solid de-icing/anti-icing chemical for use at airports. A research effort in the United States funded by SHRP (project H-205: Evaluation Procedures for De-icing Chemicals) is moving in that direction for the roads environment and it is anticipated that a large number of the evaluation procedures resulting from this 3-year project could be transferable to an airport environment. Results from this project should be available in early 1991. Unique but important airport considerations that should be researched and appended onto a project such as H-205 could be:

- airframe and power plant materials considerations
- anti-icing vs de-icing capabilities.

For the airport environment, a committee has been established in the United States to rework the present series of Aerospace Materials Specifications (AMS 1426A for liquid runway de-icers/anti-icers) and redefine AMS 1730A (urea) to accommodate any solid

Table VI-1. Summary Table of De-Icer/Anti-Icer R&D Gaps

	UREA	CMA	NaFo
TECHNICAL SPECIFICATIONS		. generic solid de-icer/anti-icer spec required	. generic solid de-icer/anti-icer spec required
AIRCARFT MATERIALS COMPATIBILTY	. applicability of existing tests and chemical exposure rates for tests (e.g. worst case, average) . engine ingestion research	. applicability of existing tests and chemical exposure rates for tests (e.g. worst case, average) . engine ingestion research . comparative tests with alternatives required	. applicability of existing tests and chemical exposure rates for tests (e.g. worst case, average) . engine ingestion research . comparative tests with alternatives required
ENVIRONMENTAL IMPACT		. oxygen depletion at actual runway loadings . heavy metals mobilization . acetate mobility . soil microcommunity that develops around CMA exposure . soil saturation rate of major cations	. surface and ground water quality . soil and vegetation impacts . aquatic biota impacts . human and animal health risks
RUNWAY MATERIALS COMPATIBILITY		. comparative tests with alternatives required	. comparative tests with alternatives required
FIELD TRIALS		. comparative tests with alternatives required	. comparative tests with alternatives required
BENEFIT/COST		. incremental benefit/cost analysis required (relative to urea)	. incremental benefit/cost analysis required (relative to urea)

runway chemical. Progress has been slow in this area up until now. However, a new draft specification (J88BM) has been recently submitted to the SAE and the committee seems to be moving faster now than in the past.

Aircraft Materials Compatibility

Admittedly some discussion of the Aerospace Materials Specifications in the Technical Specifications section does over lap with this section. However, the Technical Specifications section deals with the development of comprehensive test procedures for all chemicals and the Aircraft Materials Compatibility section deals with compliance to the specifications presently in place.

Testing done in accordance with AMS 1426A has identified CMA and NaFo as staining aluminium. However, independent tests also show that the tap water and distilled water used in the sandwich corrosion test as staining aluminium. An evaluation of the functionality of the test should be looked into before qualifying or disqualifying any further potential airport runway de-icer/anti-icer. The various procedures within the urea specification, AMS 1730A, have become more stringent over time. As a result, urea presently fails its own specification, however, no alternative currently exists.

A second area requiring attention is the engine ingestion concern. Although this concern was brought to our attention as a result of the sodium content of the sodium formate de-icer, no such engine ingestion tests have been conducted on urea or CMA either. The Structures and Materials Lab at NRC in Ottawa presently houses a burner rig consisting of a straight-line Pratt and Whitney gas turbine engine. Testing presently concentrates on evaluating protective coatings for turbine parts when subjected to high salt levels in the inlet air stream. Sodium or salt ingestion from the atmosphere into the hot end of a turbine engine combines with sulphur produced by the combustion process and produces Na_2S0_4. Sodium sulfate erodes super alloys. Contaminating the inlet air with the various chemicals and documenting their relative performance is an identified R & D requirement. Gas turbine engine manufacturers have to endorse the chemicals used on and around aircraft or the airports won't use them for engine warranty reasons. Presently, Pratt and Whitney and General Electric reluctantly accept urea and ethylene glycol based liquid de-icers such as UCAR (tradename for Union Carbide ethylene glycol).

Environment Impact

The substantial amount of environmental research and development work which has been conducted on CMA in a road environment appears to be totally transferrable and applicable to the airport environment. These tests include standard procedures documented in references such as Standard Methods for the Examination of Water and Wastewater for aquatic toxicity, soil leaching and others.

The University of Washington work included laboratory and controlled field plot experiments which demonstrated CMA transport into and its effects on the environment. However, this study also lists the following issues which are in need of verification:

1) actual CMA concentrations and mass loadings that enter surface receiving waters with runoff and the extent of dissolved oxygen depletion that result

2) the extent of trace metal mobilization in actual exposed soils; concentrations of these metals occurring in soil water, groundwater, and surface runoff

3) acetate mobility in soils with actual application rates; especially its extent and consequences in groundwater

4) composition of the soil microbial community that develops with actual CMA additions

5) the rate at which soils become saturated with major cations.

6) the impact of CMA on aquatic biota.

At the present, the Federal Highway Administration has no plans to continue environmental research in this area. It is anticipated that the Strategic Highway Research Program will address these remaining questions in its present research program; The Evaluation of Procedures for De-icing Chemicals (H205).

Even though preliminary impacts can be identified for sodium formate based on its similarities/differences with sodium chloride, sodium formate is a recent addition to the candidate alternative de-icer spectrum and needs to be evaluated with respect to its environmental issues. These issues and impacts should be compared with urea.

Runway Materials Compatibility

Similar to much of the work conducted on the roads side for the environmental area, research conducted on the road side for concrete and rebar compatibility is transferrable to the airport runway environment.

Concrete scaling is most severe with urea, followed by sodium formate and least with CMA.

Steel corrosion rate results place CMA at the same level as distilled water and sodium formate at an even lesser rate when tested in new bridge decks or structures. In the highway environment, there remains the question of CMA's corrosion inhibiting properties when used on NaCl contaminated concrete and rebar. Thus, CMA's corrosion inhibiting properties when used on urea contaminated concrete and rebar needs to be determined. Urea's relative performance was not documented in any of the references reviewed. Urea's rebar corrosion properties relative to NaFo and CMA need to be verified.

Operational Effectiveness

The only field trials of de-icing/anti-icing chemicals conducted in an airport environment (Brunswick, Maine, 1988) by the FAA were deemed very preliminary and inconclusive . Plans to expand these much needed trials this winter are already in progress. Even though the plans include abrasives as well as chemicals in de-icing mode, there is a need to include monitoring the chemicals performance in anti-icing mode. This anti-icing testing is a unique requirement to an airport environment. Complementary work on correlating runway surface friction measurements to actual aircraft braking performance is also being conducted as a joint program between the FAA and NASA.

Field trials conducted in the urban or rural roads environment does give an indication of alternative chemicals de-icing performance. However, airports wouldn't have the same traffic to help speed up the de-icing effect as city roads or highways. In addition, these highway field trials have not tested the chemicals anti-icing properties. Nor can a highway maintenance fleet give the level of attention to a certain road area that an airport snow removal fleet can give a runway. These additional variables make it necessary to conduct specifically designed airport runway field trials.

Cost/Benefit Analysis

Although some of the phenomena that affect a cost/benefit analysis performed for the road environment (i.e., concrete or rebar compatibility, vehicle corrosion, environmental impact) also affect an airport environment, the degree to which each is affected is quite different. For example, the actual area an airport snow and ice control crew has to maintain is at least an order of magnitude less than that of a municipality. Similarly the vehicle fleet which uses the maintained surface is much smaller for an airport than a municipality. The environmental impacts of applying runway de-icers are substantially less far reaching for an airport than for a municipality.

In combination with this "order of magnitude" difference between common key parameters, the airport environment cost/benefit analysis must accommodate additional variables such as:

- rerouting or delay costs as a result of runway closures
- aircraft deterioration

A variable such as delay costs has been addressed in studies before (i.e. airport applications for upgrading instrument landing systems are based on a thorough cost/benefit analysis performed by Transport Canada). However, delay costs have not been used in a cost/benefit analysis for airport snow and ice control.

In summary, information from other cost/benefit analyses performed for road environments can be drawn upon to aid in the design of a cost/benefit model for airport runway de-icing/anti-icing. The national economic analysis of a de-icer program mentioned in section II-F answered questions on the relative dollar values of each area of impact (e.g., vehicle corrosion, water quality, etc.). But at the same time this study raised questions on the local level. The area of an airport environment benefit/cost analysis is sufficiently different such that a thorough, ground-up, first-principals type approach must be under-taken on a local level so that Transport Canada can make a de-icing chemical decision on an individual airport basis.

VII CONCLUSIONS AND RECOMMENDATIONS

The study concluded that there is very little information directly comparing the performance of urea to any potential alternative runway de-ice/anti-icer in the highway environment. This fact is also true for the airport environment. The relative performance of urea to CMA and sodium formate in an airport environment, for the most part, is speculative based on previous highway research results. Therefore, it is recommended that research on the knowledge gaps identified in Section VI be investigated before Transport Canada endorse the wide-spread use of CMA or sodium formate. If Transport Canada pursues research into any alternative de-icers/anti-icers for use on airport runways, the six subject areas investigated in this report have been priorized by the Project Steering Committee as follows:

1) Aircraft Materials Compatibility
2) Operational Effectiveness
3) Environmental Impact
4) Runway Materials Compatibility
5) Cost/Benefit
6) Technical Specifications

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APPENDIX A

AK-72-40-300

Manual of Snow Removal and Ice Control

Material Requirements

AK-72-40-300

MANUAL OF SNOW REMOVAL AND ICE CONTROL

MATERIAL REQUIREMENTS

OPR: DGK/DKF/KFM/A APRIL 1983

1.00 POLICY

Refer to Chapter AK-72-40-003.

2.00 SCOPE

This chapter identifies the solid chemicals that are approved for use on airports and establishes the criteria by which chemicals are evaluated to determine their operational effectiveness.

3.00 DEFINITIONS

Refer to Chapter AK-72-40-004.

4.00 SPECIFICATIONS

(a) Standard

Snow and ice control materials used on airport surfaces shall be in accordance with the following specifications:

Sodium Chloride	NaCl	ICCS-S
Calcium Chloride	$CaCl_2$	ICCS-C
Sand No. 4		ICAS-S4
Urea		ICCS-U

Note: No ice control agent or material shall be used on the airside (other than those products specified) without prior approval of the Airport Facilities Branch (KFM), Ottawa.

(b) Guideline

At sites where Sand No. 4 is not available, other sand or aggregate may be used provided it is approved by air carriers using the site.

5.00 CHEMICALS – AIRSIDE

5.01 Urea

(a) Standard

Urea shall be used as both an anti-icer and a de-icer on airside areas. Urea is currently the only approved chemical for airside application.

6.00 CHEMICALS – GROUNDSIDE

6.01 Sodium Chloride or Calcium Chloride

(a) Standard

Solid chemicals, sodium chloride (common salt) and calcium chloride, shall be used only on the groundside areas of an airport.

7.00 SAND (CRUSHED ROCK AGGREGATE)

(a) Standard

Sand used on aircraft movement areas, shall conform to Transport Canada Specification ICAS-S4, unless conditions related in Section 4.00 apply.

(b) Guidelines

(i) Large aggregates may cause damage to propellers and aircraft surfaces, while small pieces are less effective in improving the coefficient of friction and may cause engine ingestion damage.

(ii) Sand is also used on the groundside.

8.00 UREA – ICE CONTROL MATERIAL SUPPLIERS

(a) Standard

Only approved manufacturers of ice control materials shall be requested to submit tenders.

9.00 STATISTICAL DATA

9.01 Ice Control Log Book

(a) Guideline

A record of ice control use should contain the following data:

(i) application number;
(ii) date of application;
(iii) time of application;
(iv) location (runway or taxiway designation);
(v) area treated (m^2);
(vi) amount (kg) used;
(vii) anti-icing or de-icing;
(viii) ice thickness (cm);
(ix) air temperature (°C);
(x) pavement temperature (°C);
(xi) wind speed (km/h);
(xii) wind direction (degrees);
(xiii) effectiveness;
(xiv) length of time taken to remove ice;
(xv) JBI before application (on runway only);
(xvi) JBI after application (on runway only).

10.00 UREA

10.01 Properties

(a) Guidelines

(i) Urea is approved for use in Canada on aircraft movement surfaces for the purpose of control of ice and compacted snow. The most suitable form of urea is granular or pellet. The particles are spherical and uniform in size and fall between the No. 6 and 20 Tyler sieve sizes. The grains may be coated with clay or mineral oil to prevent caking and bridging. It is free-flowing and can be satisfactorily applied with conventional sanding equipment. Because of appreciable material cost, equipment calibration and application rate should be precisely controlled.

(ii) Urea is effective in preventing the formation of ice and in de-icing down to -10°C (for all practical purposes the pavement temperature). Its density is about 750 kg/m^3, or approximately half that of sand, and is not noticeably displaced by moderate wind after application.

(iii) Urea is non-toxic and may be stored in a building (heated or unheated) in its original sealed waterproof bags for a number of years without deterioration. Urea may also be stored in bulk inside a building.

10.02 Application

(a) Standards

(i) When urea is used as a de-icer, as much snow and surface ice as possible shall first be removed by plowing and/or sweeping.

(ii) Once urea has been applied, the treated areas shall be visually inspected every half hour (or as conditions warrant) to detect the change of the ice to slush so that it can quickly be removed by plow or sweeper.

(iii) The availability of urea to assist in the control of ice on pavement surfaces shall not in any way allow a relaxation of the highest standard of snow removal techniques.

(iv) If a spreader is specifically assigned to handle urea at a site, this unit shall be filled with urea upon receipt of a weather forecast predicting icing conditions.

(v) Urea spreaders shall be cleaned after operation and checked to ensure that everything is in order and ready for the next storm.

(b) Guidelines

(i) When urea is used as an anti-icer, a spreading rate of 12.8 kg/1000 m^2 should be sufficient. Only the centre 25 m to 30 m of the runway should be treated during crosswinds of less than 15 km/h; application over this area is approximately 300 kg per each 1000 m of runway length. When there is a strong crosswind affecting the urea distribution, the spreader vehicle should be driven on the windward side of the runway centre-line and the spread width adjusted to suit the conditions and desired coverage.

Since the presence of a strong crosswind coupled with the slippery runway surface makes it more difficult for the pilot to control his aircraft, a cleared/treated width greater than 25 m should be provided depending upon the magnitude of the crosswind.

(ii) When used to assist in the removal of ice, the urea spread rate should be doubled to 600 kg per each 1000 m of runway length.

(iii) Although urea possesses de-icing qualities, it is considered to be essentially an anti-icer. It is most effective when the pavement is wet and freezing temperatures are forecast, or when rain is forecast and the pavement temperature is below freezing. When the temperature of the pavement surface is above 0°C, there is, obviously no purpose in applying urea. It will therefore be necessary to obtain the pavement temperature. This can be done by placing a thermometer on the pavement and allowing it to remain in place for several minutes. The thermometer should be hooded or shielded to prevent it from being affected by the surrounding air temperature or the sun. The thermometer must be tilted to allow the mercury bubble to contact the pavement.

(iv) The action of urea in lowering the freezing point of water allows time for sweeping the water away to prevent the formation of ice on the pavement.

(v) The effectiveness of urea is determined by the amount of dilution. Urea has a prolonged residual effect lasting several days.

(vi) If the ambient temperature is below -10°C and sanding is necessary, it is expected that an application of urea immediately prior to sanding will increase the bonding qualities and provide a higher coefficient of friction. This will facilitate the removal of ice.

(vii) When applying urea as an anti-icer during windy conditions, wait until the pavement is wet or rain begins to retain urea on the surface.

(viii) During urea application on a runway or taxiway, the foreman or the leadhand should follow behind the spreader to ensure correct application, speed, and pattern width.

11.00 ICE CONTROL SAND

11.01 Characteristics

(a) Standard

Details of acceptable sand aggregate are found in Transport Canada Specification ICAS-S4. The moisture content of ice control sand delivered to an airport site shall not exceed 3 per cent.

(b) Guidelines

Sand is used on icy aircraft manoeuvring surfaces to improve aircraft braking action when the local temperatures are below those recommended for urea use. Sand density should be about 1600 kg/m^3.

11.02 Application

(a) Standards

(i) Sand shall normally be used for ice control on aircraft manoeuvring areas when the local temperature is below -10°C and use of urea is no longer effective.

(ii) Since sand is potentially harmful to aircraft components, it shall be removed quickly by the sweeper when it has served its purpose.

(b) Guidelines

(i) Sand should be applied at a rate of 50 to 60 kg per 1000 m^2.

(ii) Normally, only the centre 25 m of the runway should be treated; however, if a substantial portion of the runway width is ice-covered and a strong crosswind is present, the total runway surface should be sanded in an effort to counter the sand displacement caused by wind action and to provide a greater usable surface.

(iii) If a spreader is specifically assigned to handle sand at a site, this equipment should be kept full of dry sand and stored inside, ready for use.

AK-72-40-399

MATERIAL REQUIREMENTS

APPENDIX

OPR: DGK/DKF/KFM/A APRIL 1983

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APPENDIX A

APPROVED SUPPLIERS OF ANTI-ICING UREA

FIRM	HEAD OFFICE	SALES OFFICE
Canadian Industries Limited	Canadian Industries Limited P.O. Box 10 Montréal, Québec H3C 2R3	Canadian Industries Limited P.O. Box 10 Montréal, Québec H3C 2R3 Canadian Industries Limited 119 St. James Street Winnipeg, Manitoba R3C 2V5 Canadian Industries Limited 45 Sheppard Avenue Willowdale, Ontario M2N 5S8 Canadian Industries Limited 800 Terminal Avenue Vancouver, British Columbia V6A 2M8 Canadian Industries Limited 4616-76th Avenue Edmonton, Alberta T6B 0A5 Canadian Industries Limited 39 Gurholt Drive Burnside Industrial Park Dartmouth, Nova Scotia B2Y 3Z6
Cominco Limited	Cominco Limited 200 Granville Square Vancouver, British Columbia V6C 2R2	Cominco Limited 130-7330 Fisher Street S.E. Calgary, Alberta T2H 2H8 Attn: J.W. Merryfield Cominco Limited 966 Waverley Street Winnipeg, Manitoba R3T 4M5

FIRM	HEAD OFFICE	SALES OFFICE
Cyanamid of Canada Limited	Cyanamid of Canada Limited 635 Dorchester Blvd. W. Montréal, Québec H3B 4A6	Cyanamid of Canada Limited P.O. Box 1039 Baie d'Urfe, Québec H9X 3N7 Cyanamid of Canada Limited Plaza One - 2000 Argentia Road Mississauga, Ontario L5N 1P7
Genstar Chemical Limited	Genstar Chemical Ltd. 1255 University Street Suite 1420 Montréal, Québec H3B 3X1	Genstar Chemical Limited 1255 University Street Suite 1420 Montréal, Québec H3B 3X1 Genstar Chemical Limited Maitland, Ontario K0E 1P0
Sherritt-Gordon Mines Limited	Sherritt-Gordon Mines Limited Commerce Court West Toronto, Ontario	Sherritt-Gordon Mines Limited 1313 T-D Tower Edmonton Centre Edmonton, Alberta T5J 2Z1 United Grach Growers Limited Winnipeg, Manitoba
Simplot Chemial Company Limited	Simplot Chemical Company Limited P.O. Box 940 Brandon, Manitoba Attn: K.R. Einarson	

APPENDIX B

Transport Canada

Urea Specification

ICCS-U

PART 1 - GENERAL

1.1 Description of Materials

.1 Supply the Department of Transport, Airports Authority Group, the quantity of [_____] tonnes of urea as specified in the Invitation to Tender.

1.2 Delivery

.1 Urea: packaged in moisture-proof bags, each containing not more than 25 kilogram.

.2 Bag size normally supplied shall be stated when submitting tender.

1.3 Acceptance Inspection

.1 Subject to verification by consignee at destination. (DSS clause T.1 or C.492 applies, as applicable).

.2 Successful tenderer(s) are to certify that the product, (urea), meets all requirements of the description as per Part 2 - Products, and have a certificate of analysis reflecting same accompanying each shipment to all consignees regardless of quantities involved in call-up(s) affected.

1.4 Condition

.1 The urea shall be in pellet or granular form and free flowing. Lumpy or caked material is unacceptable and shall be rejected by the consignee.

.2 The urea shall also be manufactured in such a manner as to be effective and perform as an anti-icing agent and not just fertilizer.

PART 2 - PRODUCTS

2.1 Materials

.1 The Urea supplied shall conform to the following requirements and will be tested accordingly:

TEST	REQUIREMENT	TEST METHOD
Nitrogen, (percent by weight)	46.0 minimum 46.7 maximum	ASTM E258 using 0.5 N acid and a 0.50 to 0.60 g sample.
Biuret (percent by weight)	1.5 maximum	Chapter 2 of AOAC exclude making up of the ion exchange column; prepare standard curve using 5 ml, 25 ml quantities; and use a 2 gram sample.
Moisture (percent by weight)	0.5 maximum	ASTM E203

.2 Particle Size

Percent retained on (percent by weight) 3.35 mm (No. 6)	2 maximum	(CGSB 2-GP-11, Method 16.2 except shake gently by hand for 3 minutes)
Percent retained on 1.18 mm (No. 16)	85 minimum	
Percent retained on 850 microns (No. 20)	97 minimum	

.3 Conditioning Agent

Formaldehyde (percent by weight) See .2 below.	0.5 maximum	N10SH 125 See .1 below.

.1 Dissolve 1 gram sample in 1 litre of water. Carry a 1 millilitre aliquot through the procedure as in N10Sh 125 for color development. Prepare calibration curve using concentrated formaldehyde solution plus the amount of Urea present in sample. The chromotropic acid complex shall read at 580 nm.

.2 Formaldehyde shall be used as a conditioning agent uniformly distributed throughout the prill and not concentrated on it's surface.

APPENDIX C

Aerospace Material Specification

AMS 1730A

Urea Compound, Shotted

SAE The Engineering Resource For Advancing Mobility

400 Commonwealth Dr., Warrendale, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

SAE AMS 1730A

Issued 10-15-79
Revised 1-1-86

Superseding AMS 1730

UREA COMPOUND, SHOTTED

1. SCOPE:

1.1 Form: This specification covers a urea compound in the form of a solid.

1.2 Application: Primarily for use in deicing airport ramps, walkways, and other ground surfaces as required.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Recommended Practices shall apply. The applicable issue of other documents shall be as specified in AMS 2350 except that the issue of APHA and AOAC publications in effect on date of invitation to bid or request for proposal shall apply.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2825 - Material Safety Data Sheets
AMS 4049 - Aluminum Alloy Sheet and Plate, Alclad, 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (Alclad 7075; -T6 Sheet, - T651 Plate)

2.1.2 Aerospace Recommended Practices:

ARP 1511 - Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals
ARP 1512 - Corrosion of Aluminum Alloys by Aircraft Maintenance Chemicals, Sandwich Test

SAE Technical Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

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2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D1119 - Ash Content of Engine Antifreezes, Antirusts, and Coolants
ASTM D1193 - Reagent Water
ASTM D1353 - Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products
ASTM D1568 - Sampling and Chemical Analysis of Alkylbenzene Sulfonates
ASTM E324 - Relative Initial and Final Melting Points and the Melting Range of Organic Chemicals
ASTM F483 - Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
ASTM F484 - Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
ASTM F502 - Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
ASTM F503 - Preparing Aircraft Cleaning Compounds, Liquid Type, for Storage Stability Testing
ASTM F519 - Mechanical Hydrogen Enbrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

MIL-P-83310 - Plastic Sheet, Polycarbonate, Transparent

2.3.2 Military Standards:

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

2.4 APHA Publications: Available from American Public Health Association, 1015 Eighteenth Street, N.W., Washington DC 20036.

APHA Standard Methods for Examination of Water and Wastewater

2.5 AOAC Publications: Available from Association of Official Agricultural Chemists, P.O. Box 540, Benjamin Franklin Station, Washington, DC 20004.

Official Methods of Analysis of the Association of Official Agricultural Chemists

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall be a uniform compound of shotted urea and shall comply with the following chemical requirements, determined in accordance with specified test methods from APHA Standard Methods for Examination of Water and Wastewater:

		Method No.
Free Ammonia (NH_3), max	300 ppm	132
Chlorides	None	112A
Iron, max	2 ppm	124A, B, or C
Sulfides	None	157
Sulfates (SO_4)	None	156C
Nitrogen, min	46%	135

3.1.1 Moisture: Shall be not more than 0.40%, determined in accordance with ASTM D1568.

3.2.1 Biuret: Shall be not more than 2.1%, determined in accordance with Official Methods of the Association of Official Agricultural Chemists, Chapter 2, excluding ion exchange column. Prepare a standard curve using 5 mL, 15 mL, and 25 mL quantities and using a 2-g sample.

3.1.3 Ash: Shall be not higher than 0.1% by weight, determined in accordance with ASTM D1119.

3.2 Properties: Urea compound shall conform to the following requirements; tests shall be performed in accordance with specified test methods on the product supplied in concentrated form and at use diultion as specified:

3.2.1 On Concentrated Urea Compound:

3.2.1.1 Temperature Stability: Urea compound shall show no chemical or physical deterioration, including evidence of discoloration or other change denoting loss of stability, after being exposed for 120 hr ± 1 at 2°C ± 3 (35°F ± 5).

3.2.1.2 Effect on Painted Surfaces: Urea compound shall neither decrease the hardness of the paint film by more than two pencil hardness levels nor shall it produce any streaking, discoloration, or blistering of the paint film, determined in accordance with ASTM F502.

3.2.1.3 Storage Stability: Urea compound shall be stable in storage for not less than 12 months at room temperature and shall not deliquesce or otherwise deteriorate when stored in shipping container or use package, determined in accordance with ASTM F503.

3.2.1.4 Nonvolatile Matter: Shall be determined in accordance with ASTM D1353 and the results reported.

3.2.1.5 Melting Point: Shall be not lower than 132°C (270°F) and not higher than 133°C (272°F), determined in accordance with ASTM E324.

3.2.2 On Diluted Urea Compound: Shall be as follows, determined on a 25% ASTM Ø D1193, Type IV, water solution of the urea:

3.2.2.1 Residue: Urea solution shall leave no residue or stains on AMS 4049 aluminum alloy, determined as in 3.2.2.1.1.

3.2.2.1.1 Two 2 x 6 in. (50 x 150 mm) panels of AMS 4049 aluminum alloy shall be cleaned with acetone and immersed in the urea solution so as to cover approximately one-half of the panel. After the urea solution has been applied, the panels shall be placed at 45 deg ± 5 from the horizontal in an oven maintained at 38°C ± 1 (100°F ± 2) for 30 min. ± 1, removed from the oven, rinsed with room temperature methyl ethyl ketone, allowed to dry, and the treated and untreated areas of the panels visually examined and compared for the presence of residue and stains.

3.2.2.2 Corrosion of Metal Surfaces:

3.2.2.2.1 Sandwich Corrosion: Two 2 x 6 in. (50 x 150 mm) panels of AMS 4049 aluminum alloy, after test, shall show a rating not worse than 1, determined in accordance with ARP 1512.

3.2.2.2.2 Total Immersion Corrosion: Urea solution shall neither show evidence of pitting or corrosion of the panels nor cause a weight change of any test panel of AMS 4049 aluminum alloy greater than 0.3 mg/cm^2 per 24 hr, determined in accordance with ASTM F483.

3.2.2.2.3 Low-Embrittling Cadmium Plate: Test panels coated with low-embrittling cadmium plate shall not show a weight change greater than 0.3 mg/cm^2 per 24 hr, determined in accordance with ARP 1511.

3.2.2.3 Hydrogen Embrittlement: Urea solution shall be non-embrittling, determined in accordance with ASTM F519, Types 1a, 1c, or 2a.

3.2.2.4 Effect on Transparent Plastics: Urea solution shall not craze, stain, Ø or discolor Type C acrylic plastic, determined in accordance with ASTM F484. The urea solution shall not craze, stain, or discolor MIL-P-83310 polycarbonate plastic or polysulfone plastic, determined in accordance with test procedures specified in ASTM F484 on specimens stressed to an outer fiber stress of 3000 psi (20 MPa) for 30 min. ± 2.

3.3 Quality: Urea compound, as received by purchaser, shall be uniform, uncoated, and free from foreign materials detrimental to usage of the urea compound.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of urea compound shall supply all Ø samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the urea compound conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for composition (3.1), hydrogen embrittlement (3.2.2.3), and effect on transparent plastics (3.2.2.4) are classified as acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for temperature stability (3.2.1.1), effect on painted surfaces (3.2.1.2), melting point (3.2.1.5), residue (3.2.2.1), and corrosion of metal surfaces (3.2.2.2) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests and shall be performed prior to or on the initial shipment of the product to a purchaser, when a change in ingredients, processing, or both requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction tests material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be in accordance with all applicable requirements of ASTM D1568 and MIL-STD-105, Level S-2; a lot shall be all urea compound produced in one continuous manufacturing operation from the same lots of raw materials and presented for vendor's inspection at one time.

4.3.1 When a statistical sampling plan and acceptance quality level (AQL) have been agreed upon by purchaser and vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3 and the report of 4.5 shall state that such plan was used.

4.4 Approval:

4.4.1 Sample urea compound shall be approved by purchaser before urea for production use is supplied, unless such approval be waived by purchaser. Results of tests on production urea shall be essentially equivalent to those on the approved sample.

4.4.2 Vendor shall use ingredients, manufacturing procedures, and methods of inspection on production urea which are essentially the same as those used on the approved sample urea. If necessary to make any change in ingredients or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in material, processing, or both and, when requested, sample urea. Production urea made by the revised procedure shall not be shipped prior to receipt of reapproval.

4.5 Reports: Unless waived by purchaser, the vendor of urea compound shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance test requirements and, when performed, to the periodic test requirements and stating that the compound conforms to the other technical requirements of this specification. This report shall include the purchase order number, AMS 1730A, manufacturer's identification, lot number, and quantity.

4.5.1 A material safety data sheet conforming to AMS 2825, or equivalent, shall be

Ø supplied to each purchaser prior to, or concurrent with, the report of preproduction test results or, if preproduction testing be waived by purchaser, concurrent with the first shipment of compound for production use. Each request for modification of compound formulation shall be accompanied by a revised data sheet for the proposed formulation.

4.6 Resampling and Retesting: If any sample used in the above tests fails to meet the specified requirements, disposition of the urea compound may be based on the results of testing three additional samples for each original nonconforming sample. Failure of any retest sample to meet the specified requirements shall be cause for rejection of the urea compound represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Each container shall be legibly marked with not less than AMS 1730A, purchase order number, manufacturer's identification, lot number, and quantity.

5.2 Packaging:

5.2.1 Urea compound shall be packaged in containers of a type and size agreed upon by purchaser and vendor.

5.2.2 Containers of urea compound shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the urea compound to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

5.2.3 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-794, Level A or Level C, as specified in the request for procurement. Commercial packaging as in 5.2.1 and 5.2.2 will be acceptable if it meets the requirements of Level C.

6. ACKNOWLEDGMENT: A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Urea compound not conforming to this specification or to modifications authorized by purchaser will be subject to rejection.

8. NOTES:

8.1 Marginal Indicia: The phi (Ø) symbol is used to indicate technical changes from the previous issue of this specification.

8.2 Dimensions and properties in inch/pound units and the Celsius temperatures are primary; dimensions and properties in SI units and the Fahrenheit temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.3 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Type and size of containers desired
Quantity of urea compound desired
Applicable level of packaging (See 5.2.3)

8.4 Similar Specifications: DOD-U-10866 is listed for information only and shall not be construed as an acceptable alternate unless all requirements of this AMS are met.

8.5 Urea compound meeting the requirements of this specification has been classified under Federal Supply Classification (FSC) 6810.

This specification is under the jurisdiction of AMS Committee "J" (AMCM).

APPENDIX D

AMS Deicing/Anti-icing Compound - (Solid) Magnesium Calcium Acetate (MCA)

Draft J87BN

AEROSPACE MATERIAL SPECIFICATION

DEICING/ANTI-ICING COMPOUND - (SOLID) MAGNESIUM CALCIUM ACETATE (MCA)

1. SCOPE:

1.1 Form: This specification covers a biodegradable chemical deicing/anti-icing compound in the form of a solid.

1.2 Application: Primarily for use in deicing/anti-icing airport ramps, walkways, runways and taxiways.

1.3 Solid Particle Shape: MCA particles shall not be spherical.

1.4 Precautions: MCA is a stable, relatively non-toxic chemical. However, contact with the eyes and skin should be avoided. Also, prolonged breathing of MCA dust should be avoided.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Recommended Practices shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2470 - Anodic Treatment of Aluminum Alloys, Chromic Acid Process
AMS 2475 - Protective Treatments, Magnesium Alloys
AMS 2825 - Material Safety Data Sheets
AMS 4037 - Aluminum Alloy Sheet and Plate, 4.4Cu - 1.5Mg - 0.60Mn (2024; -T3 Flat Sheet, -T351 Plate)
AMS 4041 - Aluminum Alloy Sheet and Plate, Alclad, 4.4Cu - 1.5Mg - 0.60Mn (Alclad 2024 and 1-1/2% Alclad 2024-T3 Flat Sheet; 1-1/2% Alclad 2024-T351 Plate)
AMS 4049 - Aluminum Alloy Sheet and Plate, Alclad, 5.6Zn, 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (Alclad 7075; -T6 Sheet, -T651 Plate)
AMS 4376 - Magnesium Alloy Plate, 3.0Al - 1.0Zn (AZ31B-H26)
AMS 4911 - Titanium Alloy Sheet, Strip, and Plate (6Al - 4V), Annealed
AMS 5045 - Steel Sheet and Strip, 0.25 max Carbon, Hard Temper

2.1.2 Aerospace Recommended Practices:

ARP 1511 - Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals
ARP 1512 - Corrosion of Aluminum Alloys by Aircraft Maintenance Chemicals, Sandwich Test

2.2 ASTM Publications: Available from American Society for Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM C672 - Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals
ASTM E70 - pH of Aqueous Solutions with the Glass Electrode
ASTM F433 - Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
ASTM F484 - Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
ASTM F485 - Effects of Cleaners on Unpainted Aircraft Surfaces
ASTM F502 - Effects of Cleaning and Chemical Maintenance Materils on Painted Aircraft Surfaces
ASTM F519 - Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals

2.3 U. S. Government Publications: Available from Commanding Officer, Navel Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 15120

2.3.1 Military Specifications: MIL-P-83310 - Plastic Sheet, Polycarbonate, Transparent

2.3.2 Military Standards: MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

2.4 APHA Publications: Available from American Public Health Association, 1015 Eighteenth Street, N.W., Washington DC 20036

APHA Standard Methods for Examination of Water and Wastewater

3. TECHNICAL REQUIREMENTS:

3.1 Composition: MCA shall be a magnesium calcium acetate compound in which the mol fraction of magnesium, as signified by X_{Mg}, where

$$X_{Mg} = \frac{\text{mols Magnesium}}{\text{mols Magnesium + mols Calcium}},$$

falls within the range 0.8 - 1.0.

3.1.1 Impurity Levels: The level of soluble chloride shall be no higher than 1000 ppm, determined in accordance with Method 112A of APHA Standard Methods for Examination of Water and Wastewater.

3.1.2 Insolubles Level in Aqueous Solution: The level of product insolubles in a 10% by weight solution of MCA in water shall not exceed 0.5%.

3.2 Properties: MCA compound shall conform to the following requirements; tests shall bew performed in accordance with specified test methods on the product supplied, and at the use dilution (by water) as specified:

3.2.1 pH of Aqueous Solution: A 15% by weight solution of MCA in water shall exhibit a pH in the range 7.5 - 8.6, determined in accordance with ASTM E70.

3.2.2 Temperature Stability: MCA compound shall show no chemical or physical deterioration, including evidence of discoloration or other change denoting loss of stability, after being exposed for 120 hr ± 1 at 2°C ± 3 (35°F ± 5).

3.2.3 Effect on Painted Surfaces: MCA compound shall neither decrease the hardness of the paint film by more than two pencil hardness levels nor shall it produce any streaking, discoloration, or blistering of the paint film, determined in accordance with ASTM F502.

3.2.4 Storage Stability: MCA compound shall be stable in storage for not less than 12 months at room temperature and shall not deliquesce or otherwise deteriorate when stored in shipping container or use package, determined in accordance with ASTM F503.

3.2.5 Residue: MCA solution shall leave no residue to stains on AMS 4049 aluminium alloy, determined as 3.2.5.1.

3.2.5.1 Two 2 x 6 in. (50 x 150 mm) panels of AMS 4049 aluminum alloy shall be cleaned with acetone and immersed in a 15% by weight MCA solution so as to cover approximately one-half of the panel. After the solution has been applied, the panels shall be placed at 45 deg. + 5 from the horizontal in an oven maintained at 38°C + 1 (100°F + 2) for 30 min. + 1, removed from the oven, rinsed with room temperature methyl ethyl ketone, allowed to dry, and the treated and untreated areas of the panels visually examined and compared for the presence of residue and stains.

3.2.6 Corrosion of Metal Surfaces: MCA solution shall conform to the following requirements, where aqueous solution concentration is 15% by weight:

3.2.6.1 Total Immersion Corrosion: The solution shall neither show evidence of corrosion of panels nor cause a weight change of any test panel greater than the following, determined in accordance with ASTM F483.

Test Panel	Weight Change mg/cm^2 per 24 hr.
AMS 4037 Aluminum Alloy, anodized as in AMS 2470	0.3
AMS 4041 Aluminum Alloy (Optional)	0.3
AMS 4049 Aluminum Alloy	0.3
AMS 4376 Magnesium Alloy, dichromate treated as in AMS 2475	0.2
AMS 4911 Titanium Alloy	0.1
AMS 5045 Carbon Steel	0.8

3.2.6.2 Low-Embrittling Cadmium Plate: Test panels coated with low-embrittling cadmium plate shall not show a weight change greater than 0.3 mg/cm^2 per 24 hr, determined in accordance with ARP 1511.

3.2.6.3 Hydrogen Embrittlement: The solution shall be non-embrittling, determined in accordance with ASTM F519, Types 1a, 1c, or 2a.

3.2.6.4 Sandwich Corrosion: Specimens of AMS 4037 and AMS 4049 aluminum alloy, after test, shall show a rating not worse than 2, determined in accordance with ARP 1512.

3.2.7 Effect on Transparent Plastics: The 15% solution shall not craze, stain, or discolor Type C acrylic plastic, determined in accordance with ASTM F484. The fluid shall not craze, stain, or discolor MIL-P-83310 polycarbonate plastic or polysulfone plastic, determined in accordance with test procedures specified in ASTM F484 on specimens stressed for 30 min. + 2 to an outer fiber stress of 3000 psi (20 MPa).

3.2.8 Pavement Compatibility:

3.2.8.2 Scaling Resistance: The condition of the surface shall have a rating not greater than 2, determined in accordance with ASTM C672 except that a 15% by weight solution of the deicer/anti-icer in tap water shall be substituted for calcium chloride.

3.2.8.2 Slipperiness: Friction limits shall be as follows, determined on concrete and asphalt surfaces, both wet and dry, using a Mu meter and with a 15% deicer/anti-icer solution thickness of 1 mm (0.04 in.) using a NASA depth gauge. A basis reading shall be determined on wet and dry concrete and wet and dry asphalt before application of the deicer/anti-icer solution.

3.2.8.2.1 Wet Concrete: Shall be not less than the following:

Initial Reading - 45% of basis reading on wet concrete
After 15 min. - 60% of basis reading on wet concrete
After 30 min. - 65% of basis reading on wet concrete
After 45 min. - 68% of basis reading on wet concrete
After 60 min. - 75% of basis reading on wet concrete

3.2.8.2.2 Dry Concrete: Shall be not less than the following:

Initial Reading - 0.25 on Mu meter scale
At least 75% of the readings after 15 min., after 30 min., after 45 min., and after 60 min. shall be 0.34 or higher on Mu meter scale.

3.2.8.2.3 Wet Asphalt: All readings, as in 3.211.2.1, shall be not less than 85% of the basis reading on wet asphalt.

3.2.8.2.4 Dry Asphalt: All readings, as in 3.2.11.2.1, shall be not less than 85% of the basis reading on dry asphalt.

3.2.9 Biodegradability: The aqueous solution of MCA shall not be less than 90% biodegradable. Results of biodegradability studies conducted in accordance with the latest edition of "Standard Methods for the Examination of Water and Waste Water", published by the U.S. Public Health Service, for biodegradability and bioassays shall, when requested by purchaser, be provided by the fluid manufacturer to purchaser and shall contain not less than the following information:

3.2.9.1 A statement of the ecological behavior of the MCA compound.

3.2.9.2 A 5-day total oxygen demand (TOD) of the compound, expressed in pounds-oxygen to pounds MCA.

3.2.9.3 Percent degraded in 5 days.

3.2.9.4 Presence, in percentages by weight, of sulfur, halogens, phosphate, nitrate, and heavy metals (lead, chromium, cadmium, mercury).

3.3 Quality: MCA compound as received by the purchaser shall be uniform, free-flowing and free from foreign materials detrimental to its usage.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of MCA compound shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the MCA compound conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for composition (3.1), hydrogen embrittlement (3.2.6.3), and effect on transparent plastics (3.2.7) are classified as acceptnce tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for temperature stability (3.3.2), effect on painted surfaces (3.2.3), residue (3.2.5), and corrosion of metal surfaces (3.2.5) are classifided as periodic tests and shall be performed at a frequfency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classifed as preproduction tests and shall be performed prior to or on the initial shipment of the product to a purchaser, when a change in ingredients, processing,or both requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, whenm requested, preproduction tests material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be in accordance with all applicable requirements of ASTM D1568and MIL-STD-105, Level S-2; a lot shall be all MCA compound produced in one continuous manufacturing operation from the same lots of raw materials and presented for vendor's inspection at one time.

4.3.1 When a statistical sampling plan and acceptance quality level (AQL) have been agreed upon by purchaser and vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3 and the report of 4.5 shall state that such plan was used.

4.4 Approval:

4.4.1 Sample MCA compound shall be approved by purchaser before MCA for productio use is supplied, unless such approval be waived by purchaser. Results of tests on production MCA shall be essentially equivalent to those on the approved sample.

4.4.2 Vendor shall use ingredients, manufacturing procedures, and methods of inspection on production MCA which are essentially the same as those used on the approved sample MCA. If necessary to make any change in ingredients or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in material, processing, or both and, when requested, sample MCA. Production MCA made by the revised procedure shall not be shipped prior to receipt of reapproval.

4.5 Reports: Unless waived by purchaser, the vendor of MCA compound shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance test requirements and, when performed, to the periodic test requirements and stating that the compound conforms to the other technical requirements of this specification. this report shall include the purchase order number, AMS 1730A, manufacturer's identification, lot number, and quantity.

4.5.1 A material safety data sheet conforming to AMS 2825, or equivalent, shall be supplied to each purchaser prior to, or concurrent with, the report of preproduction test results or, if preproduction testing be waived by purchaser, concurrent with the first shipment of compound for production use. EDach request for modification of compound formulation shall be accompanied by a revised data sheet for the proposed formulation.

4.6 Resampling and Retesting: If any sample used in the above tests fails to meet the specified requiremnents, disposition of the MCA compound may be based on the results of testing three additional samples for each original nonconforming sample. Failure of any retest sample to meet the specified requirements shall be cause for rejection of the MCA compound represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Each container shall be legibly marked with not less than , purchase order number, manufacturer's identification, lot number, and quantity.

5.2 Packaging:

5.2.1 MCA compound shall be packaged in containers of a type and size agreed upon by purchaser and vendor.

5.5.2 Containers of MCA compound shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the MCA compound to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

5.2.3 For direct U./S. Military procurement, packaging shall be in accordance with MIL-STD-794d, Level A or Level C, as specified in the request for procurement for procurement. Commercial packaging as in 5.2.1 and 5.2.2 will be acceptable if it meets the requirements of Level C.

6. ACKNOWLEDGMENT: A vendor shall mention this spoecification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS: MCA compound not conforming to this specification or to modifications authorized by purchaser will be subject to rejection.

8. NOTES:

8.1 Dimensions and properties in inch/pound units and the Celsius temperatures are primary; dimensions and properties in SI units and the Fahrenheit temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.2 For direct U.S. Military proceurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Type and size of containers desired
Quanity of urea compound desired
Applicable level of packaging (See 5.2.3)

8.3 MCA compound meeting the requirements of this specification has been classified under Federal Supply Classification (FSC)

APPENDIX E

CMA (ICE-B-GON^{R})

Conformity with the unofficial AMS Specification Deicing/Anti-icing Compound - (Solid) Magnesium Calcium Acetate

SCIENTIFIC MATERIAL INTERNATIONAL INC.

REPLY TO P.O. BOX 141797
CORAL GABLES, FLORIDA 33114
OFFICE: 7019 S.W. 13TH STREET
MIAMI, FLORIDA 33144
PHONE (305) 757-5596
TELEX 4933347 SMI UI

Chevron Chemical Company
6001 Bollinger Canyon Road
San Ramon, California 94583

Date: January 12,1988
SMI/REF: 871243

Attn: Mr. Karl Hoenke

Product: CMA

Dilution: Per specification

AMS Specification
Deicing/Anti-icing Compound-(solid) Magnesium
Calcium Acetate (MCA)

3.1.1 Impurity Levels: The level of soluble chloride shall be no higher than 1000 ppm, determined in accordance with Method 112A of APHA Standard Methods for Examination of Water and Wastewater.

Result Conform average 156 ppm

3.1.2 Insolubles Level in Aqueous Solution: The level of product insolubles in a 10% by weight solution of MCA in water shall not exceed 0.5%.

Result Conform .24% average after 24hr

3.2 Properties: MCA compound shall conform to the following requirements; tests shall be performed in accordance with specified test methods on the product supplied, and at the use dilution (by water) as specified:

3.2.1 pH of Aqueous Solution: A 15% by weight solution of MCA in water shall exhibit a pH in the range 7.5-8.6, determined in accordance with ASTM E 70.

Result Does not conform 9.38

Cont'd page 2

3.2.2 Temperature Stability: MCA compound shall show no chemical or physical deterioration, including evidence of discoloration or other change denoting loss of stability, after being exposed for 120 hr± 1 at 2°C ±3 (35°F ±5).

Result Conform Very slight darkening of product

3.2.3 Effect on Painted Surfaces: MCA compound shall neither decrease the hardness of the paint film by more than two pencil hardness levels nor shall it produce any streaking, discoloration, or blistering of the paint film, determined in accordance with ASTM F 502.

Result Conform No effect

3.2.4 Storage Stability: MCA compound shall be stable in storage for not less than 12 months at room temperature and shall not deliquesce or otherwise deteriorate when stored in shipping container or use package, determined in accordance with ASTM F 503.

Result Due Jan.1989

3.2.5 Residue: MCA solution shall leave no residue to stains on AMS 4049 aluminum alloy, determined as 3.2.5.1.

3.2.5.1 Two 2x6 in. (50 x 150 mm) panels of AMS 4049 aluminum alloy shall be cleaned with acetone and immersed in a 15% by weight MCA solution so as to cover approximately one-half of the panel. After the solution has been applied, the panels shall be placed at 45 deg.+ 5 from the horizontal in an oven maintained at 38°C +1 (100°F +2) for 30 min.+1, removed from the oven, rinsed with room temperature methyl ethyl ketone, allowed to dry, and the treated and untreated areas of the panels visually examined and compared for the presence of residue and stains.

Slight darkening & residue formed
Result Does not conform

3.2.6 Corrosion of Metal Surfaces: MCA solution shall conform to the following requirements, where aqueous solution concentration is 15% by weight:

3.2.6.1 Total Immersion Corrosion: The solution shall neither show evidence of corrosion of panels nor cause a weight change of any test panel greater than the following, determined in accordance with ASTM F 483.

Test Panel	Weight Change Mg/cm²/24hr	Found
AMS 4037 Aluminum alloy, anodized as in AMS 2470	0.3	*.3
AMS 4041 Aluminum Alloy (Optional)	0.3	*.3
AMS 4049 Aluminum Alloy	0.3	.3
AMS 4376 Magnesium Alloy, dichromate treated as in AMS 2475	0.2	.1
AMS 4911 Titanium Alloy	0.1	.1
AMS 5045 Carbon Steel	0.8	.5

* Discolor & streaking of panel

Result Does not conform

Cont'd to page

3.2.6.2 Low-Embrittling Cadmium Plate: Test panels coated with low-embrittling cadmium plate shall not show a weight change greater than 0.3mg/cm^2 per 24 hr, determined in accordance with ARP 1511.

Result Conform .17 mg average

3.2.6.3 Hydrogen Embrittlement: The solution shall be non-embrittling determined in accordance with ASTM F519, Type 1C.

Result Conform

3.2.6.4 Sandwich Corrosion: Specimens of AMS 4037 and AMS 4049 aluminum alloy, after test, shall show a rating not worse than 2, determined in accordance with ARP 1512.

	1	2	3	4
15% solution	3	3	3	3
Synthetic Tap Water	1	1	1	1

Result

3.2.7 Effect on Transparent Plastics: The 15% solution shall not craze, stain, or discolor Type C acrylic plastic, determined in accordance with ASTM F 484. The fluid shall not craze, stain, or discolor Mil-P-83310 polycarbonate plastic or polysulfone plastic, determined in accordance with test procedures specified in ASTM F484 on specimens stressed for 30 min. +2 to an outer fiber stress of 3000 psi (20 MPa).

Result Conform

3.2.8 Pavement Compatability:

3.2.8.1 Scaling Resistance: The condition of the surface shall have a rating not greater than 2, determined in accordance with ASTM C672 except that a 15% by weight solution of the deicer/anti-icer in tap water shall be substituted for calcium chloride.

Scaling greater than #3

Result Does not conform

*3.2.8.2 Slipperiness: Friction limits shall be as follows, determined on concrete and asphalt surfaces, both wet and dry, using a Mu meter and with a 15% deicer/anti-icer solution thickness of 1 mm (0.04 in) using a NASA depth gauge. A basis reading shall be determined on wet and dry concrete and wet and dry asphalt before application of the deicer/anti-icer solution.

3.2.8.2.1 Wet Concrete: Shall be not less than the following:

Initial Reading- 45% of basis reading on wet concrete	+.76
After 15 min. - 60% of basis reading on wet concrete	+.76
After 30 min. - 65% of basis reading on wet concrete	+.76
After 45 min. - 68% of basis reading on wet concrete	+.76
After 60 min. - 75% of basis reading on wet concrete	+.76

* NBS Slip & Fall Tester used

Cont'd page 4

3.2.8.2.2 Dry Concrete: Shall be not less than the following:

Initial Reading- 0.25 on Mu meter scale
At least 75% of the readings after 15 min., after 30 min., after 45 min., and after 60 min. shall be 0.34 or higher on Mu meter Scale

Result +.76

3.2.8.2.3 Wet Asphalt: All readings, as in 3.2.11.2.1 shall be not less than 85% of the basis reading on wet asphalt.

Result +.76

3.2.8.2.4 Dry Asphalt: All readings, as in 3.2.11.2.1 shall be not less than 85% of the basis reading on dry asphalt.

Result +.76

3.2.9 Biodegradability: The aqueous solution of MCA shall not be less than 90% biodegradable. Results of biodegradability studies conducted in accordance with the latest edition of "Standard Methods for the Examination of Water and Waste Water", published by the U.S. Public Health Service, for biodegradability and bioassays shall, when requested by purchaser, be provided by the fluid manufacturer to purchaser and shall contain not less than the following information:

3.2.9.1 A statement of the ecological behavior of the MCA compound.

3.2.9.2 A 5 day total oxygen demand (TOD) of the compound, expressed in pounds-oxygen to pounds MCA.

3.2.9.3 Percent degraded in 5 days.

3.2.9.4 Presence, in percentages by weight, of sulfur,halogens,phosphate, nitrate, and heavy metals (Lead,chromium,cadmium,mercury).

Result Certified by Mfg.

3.3 Quality: MCA compound as received by the purchaser shall be uniform, free-flowing and free from foreign materials detrimental to its usage.

Result Conform

Respectfully submitted,

Joseph Schruefer,Jr.

Appendix F

Sodium Formate: Conformity with AMS1426A - Liquid Runway Deicing/Anti-icing Chemicals

SCIENTIFIC MATERIAL INTERNATIONAL INC.

REPLY TO P.O. BOX 141797
CORAL GABLES, FLORIDA 33114
OFFICE: 7019 S.W. 13TH STREET
MIAMI, FLORIDA 33144
PHONE (305) 757-5596
TELEX 4933347 SMI UI
Fax (305)-893-0431

Hoechst Celanese
P.O. Box 9077
Corpus Christi, Texas 78469

Attn: Mr. Bill Slinkard

March 16,1988
SMI/REF: 880340

Report of Test

Submitted: One kg of Sodium Formate.

Requested: Test for effect on possible use as a Deicer for runway and aircraft.

Test conducted Aerospace Material Specification AMS 1426A. Deicing/ Anti-icing Fluid Runways and Taxiways, Paragraph 3.2.5.1 Sandwich Corrosion, 3.2.5.2 Total Immersion Corrosion.

Dilution: One part product to 5 parts water.

Result of Test

Paragraph 3.2.5.1 Sandwich Corrosion. Specimens of AMS 4037 and AMS 4049 aluminum alloy after test, shall show a rating not worse than 2 determined in accordance with ARP 1512.

	4037	4049
Diluted 1:5 with water	3	3
Synthetic tap water	1	1

Extreme staining of panel
Result Does not conform

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Hoechst Celanese
Product: Sodium Formate
Dilution 1:5 with water
SMI

March 16,1988
SMI/REF: 880340

Paragraph 3.2.5.2 Total Immersion Corrosion: The product shall neither show evedence of corrosion panels nor cause a change of any test panel greater than the following,determined in accordance with ASTM F-483.

	Allowed loss mg/cm^2/24hr	Found
Aluminum AMS 4037	.3	.09
Magnesium AMS 4376	.2	.19
Titanium AMS 4911	.1	.08
Stainless Steel 18-8	.1	.02
Carbon Steel 1020	.8	.50

Result Does not conform
Extreme staining on Al

Respectfully submitted,

Joseph Schruefer,Jr

CONFIDENTIAL

Client: Hoechst Celanese
Product: Sodium Formate
Dilution: 1 :5 with water by weight
CSD #1 Reissued 1-22-79

Date: February 10,1988
SMI/REF: 880207

SMI

1. Effect on Painted Surfaces Test: The material shall not produce a decrease in paint film hardness greater than one pencil; that is, the number of the next softer pencil, or any discoloration or staining when tested in accordance with ASTM F 502. At least 2 panels shall be used per test.

   Result Conform

2. Residue Test: The material shall leave no residue or stain when tested in accordance with ASTM F-485.

   Result Conform

3. Sandwich Corrosion Test: The compound shall not cause significant corrosion of aluminum alloy faying surfaces when tested in accordance with the applicable ASTM test method, or under the following conditions of temperature and humidity:

   (a) Thirty-six (36) test panels 2 x 4 x .040 inch shall be prepared as follows:

   Six each- Aluminum alloy panels P/N 7452876-7 (nonclad 2024 T-3) Federal Specification QQ-A-250/4 Temp-T3, Alodined (colorless # 1000 or 1500) per Military Specification Mil-C-5541, Class 3.

   Six each- Aluminum alloy panels P/N 7452876-9 (nonclad 2024T-3) Federal Specification QQ-A-250/4 Temp-T3, Chromic Acid anodized per Military Specification Mil-A-8625 Type 1.

   Six each- Aluminum alloy panels P/N7452876-11 (clad 2024-T3) Federal Specification QQ-A-250/5 Temp-T3, Alodined (colorless #1000 or 1500) per Military Specification Mil-C-5541, Class 3.

   Six each- Aluminum alloy panels P/N 7452876-13 (clad 2024-T3) Federal Specification QQ-A-250/5 Temp-T3, Chromic acid anodized per Military Specification Mil-A-8625 Type 1.

   Six each- Aluminum panels P/N 7452876-15 (clad 7075-T6) Federal Specification QQ-A-250/13 Temp-T6, Alodined (colorless # 1000 or 1500) per Military Specification Mil-C-5541, Class 3.

   Six each- Aluminum alloy panels P/N 7452876-17 (clad 7075 T6) Federal Specification QQ-A-250/13 Temp-T6, Chromic acid anodized per Military Specification Mil-A-8625, Type 1.

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Client: Hoechst Celanese
Product: Sodium Formate
Dilution: 1:5 with water by weight
CSD #1 Reissued 1-22-79

Date: February 10,1900
SMI/REF: 880207

SMI

3. (b) A sandwich set shall consist of two panels of the same alloy and surface finish. Assemble the panels into 3 identical groups, each having six different sets of panels, suitably identified by permanent marking.

(c) The material to be tested shall be applied at the use concentration with a clean brush to the face of one panel from each set in the first group. Dilution to use concentration, if required, will be accomplishrd with distilled water. The material shall be applied in an irregular manner and shall cover approximately one-half the panel face. The two similar panels shall be placed together in sandwich style with the test material in the faying surface between the two panels.

(d) The second group of panels will be sandwiched together in sets as described above except that the faying surface between the panel faces shall be coated with the material at the use concentration, diluted with tap water or noncrazing solvent as required.

(e) The third group of panels will be sandwiched together in sets as described above except that the faying surfaces between the panel faces shall be wet with tap water. This test may be omitted if the material is used in the concentrated form only.

(f) The three groups of panels shall be exposed at alternate intervals of 16 hours in the humidity cabinet and 8 hours in an oven. Beginning with the humidity cabinet exposure, the cycling test shall be continued for a total of seven days. The humidity cabinet shall be maintained at 100° ± 2°F (37.8° ± 1.1°C) and 98 to 100 percent relative humidity. The oven shall be maintained at 100° ± 5°F (37.8 ° ± 2.8°C). Each set of panels shall be exposed individually not stacked, in a horizontal position. After exposure, the panels shall be rinsed in warm tap water and scrubbed lightly with a soft nonmetallic bristle brush. After drying, examine each panel under 10X magnification and rate each set according to the following:

0- No visible corrosion

1- Very slight corrosion or discoloration

2- Slight corrosion

3- Moderate corrosion

4- Extensive corrosion

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Client: Hoechst Celanese
Product: Sodium formate
Dilution: 1:5 with water by weight
CSD #1 Reissued 1-22-79

Date: February 10,1988
SMI/REF: 880207
Page: 4

SMI

3. (g) The corrosion rating obtained on the sets of panels of the first and second groups shall be compared with the rating obtained on the third group. Corrosion on any panel in the first and second groups exceeding that obtained on the similar panels in the third group shall be considered as excessive.

(h) The corrosion rating obtained on the sets of panels tested with concentrated materials, for which comparison panels were not run, shall not exceed a rating of 1, as defined above.

Aluminum - (2024-T3) Alodined (colorless #1000) _____
Aluminum - (2024-T3) Anodized _____
Aluminum - (Alclad 2024-T3) Alodined (colorless) _____
Aluminum - (Alclad 2024-T3) Anodized _____
Aluminum - (Alclad 7075-T6) Alodined (colorless) _____
Aluminum - (Alclad 7075-T6) Anodized _____

Result Not tested

4. Stress Crazing Test on Acrylic Plastics: The compound shall not cause crazing crackling, or other attack of acrylic based plastics when tested in accordance with ASTM F-484, using Type C material at a stress level of 4500 psi.

Result Conform no craze

5. Immersion Corrosion Test: The average weight loss of aluminum alloy specimens shall not exceed 10 milligrams per coupon when tested per ASTM F-483. The aluminum alloy 7075-T6 alclad coupons shall conform to Federal Specification QQ-A-250/13 Temp-T6, with corners and edges smoothed.

Result Not tested

6. Cadmium Removal Test: The average weight loss of cadmiun from low-hydrogen embrittlement cadmium plated steel specimens shall not exceed 10 milligrams per coupon when tested in accordance with the applicable ASTM test method or as follows:

(a) Each of three 1 x 2 x .040 inch 4130 steel panels ,P/N 7452876-23 per Military Specification Mil-S-18729 shall be accurately weighed and the weight recorded. Each of the weighed specimens shall be

cont'd to next page

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Client: Hoechst Celanese
Product: Sodium formate
Dilution: 1:5 with water by weight
CSD#1
SMI

Date: February 10,1988
SMI/REF: 880207

Cont'd of Cadmium Removal Test

totally immersed in a minimum of 100 ml of the compound for 24 hours. The concentration of the solution shall be that which is recommended for use on the aircraft. The specimens shall then be rinsed with distilled water, acetone, and air dried. The specimens shall be placed in an oven at 395° ± 15°F. (201.7 ± 8.3°C.) for one (1) hour and allowed to cool to room temperature. The specimens shall be weighed and the average weight loss of the three specimens recorded.

Result Conform 1.4mg loss

/. Hydrogen Embrittlement Test: Hydrogen Embrittlement testing shall be in accordance with ASTM-F-519, Type 1C.

Result Conform

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APPENDIX G

AEROSPACE MATERIAL SPECIFICATION

DE-ICING/ANTI-ICING COMPOUND SOLID

(DRAFT J88BM)

ECC Marked Copy

AE 410-736-4241

AEROSPACE MATERIAL SPECIFICATION
K. A. HOENKE
10-31-88

AMS
Draft JSSBM

SOLID DEICING/ANTI-ICING ~~MATERIAL~~ COMPOUND
Solid

1. SCOPE:

1.1 Form: This specification covers ~~solid~~ deicing and anti-icing ~~materials~~ compound in the form of a solid.

1.2 Application: Primarily for use on airport runways, taxiways, ramps, walkways, and other ground surfaces as required.

1.3 Precautions:

~~1.3.1~~ The deicing/anti-icing formulation supplied under requirements of this specification may be mildly toxic and contact with human skin and eyes should be avoided. Prolonged exposure to concentrations exceeding the established threshold limit values (TLV) for the product or its major components should also be avoided.

~~1.3.2 Vendor shall supply current Material Safety Data Sheets (MSDS) for deicing/anti-icing chemicals supplied under this specification.~~

1.4 Safety-Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications ~~and Aerospace Recommended Practices~~ shall apply. The applicable issue of other documents shall be as specified in ~~the manual on the preparation of Aero Space Materials Specifications.~~ AMS 2350.

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2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications

AMS 2350 - Standards and Test Methods
AMS 2470 - Anodic Treatment of Aluminum Alloys, Chromic Acid Process
AMS 2475 - Protective Treatments, Magnesium Alloys
AMS 2825 - Material Safety Data Sheets
AMS 4037 - Aluminum Alloy Sheet and Plate, 4.4 Cu-1.5 Mg-0.60 Mn, (2024; -T3 Flat Sheet, -T351 Plate), Solution Heat Treated
AMS 4041 - Aluminum Alloy Sheet and Plate, Alclad, 4.4 Cu-1.5 Mg-0.60 Mn, (Alclad 2024 and 1½% Alclad 2024 -T3 Flat Sheet; 1½% Alclad 2024-T351 Plate)
AMS 4049 - Aluminum Alloy Sheet and Plate, Alclad, 5.6 Zn-2.5 Mg-1.6 Cu-0.23 Cr, (Alclad 7075; -T6 Sheet, -T651 Plate), Solution and Precipitation Heat Treated
AMS 4376 - Magnesium Alloy Plate, 3.0 Al-1.0 Zn, (AZ31B-H26), Cold Rolled and Partially Annealed
AMS 4911 - Titanium Alloy Sheet, Strip, and Plate, 6Al-4V, Annealed
AMS 5045 - Steel Sheet and Strip, 0.25 max Carbon, ~~Deep~~ Hard Temper ~~Forming Grade~~

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. ~~Tests to be conducted on 15 wt. % solution as defined in 3.2.~~

ASTM E70 - pH of Aqueous Solutions with the Glass Electrode
ASTM F483 - Total Immersion Corrosion Test for Aircraft Maintenance Chemicals

ASTM C871 - Chemical Analysis of Thermal Insulation Materials for Leachable Chlorides, Fluorides, Silicate, and Sodium Ions
ASTM D1568 - Sampling and Chemical Analysis of Alkybenzene Sulfonates
ASTM D4057 - Manual Sampling of Petroleum and Petroleum Products
ASTM D4177 - Automatic Sampling of Petroleum and Petroleum Products

ASTM F484 - Stress Crazing of Acrylic Plastics in Contact With Liquid ~~and~~ Semi-Liquid Compounds
ASTM F519 - Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals
ASTM F1110 - Sandwich Corrosion Test
ASTM F1111 - Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals

2.3 **U.S. Government Publications:** Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabot Avenue, Philadelphia, PA 19120

2.3.1 **Military Specifications:**

MIL-P-83310 - Plastic sheet, polycarbonate, transparent.

2.3.2 **Military Standards:**

MIL-STD-794 - Parts and equipment, Procedures for Packaging and packing of

2.4 **APHA Publications:** Available from American Public Health Association, 1015 Eighteenth Street, NW, Washington, DC 20036

Standard Methods for the Examination of Water and Waste Water

3. **TECHNICAL REQUIREMENTS**

3.1 **Material:** The composition of the ~~solid~~ deicer compound shall be at least 90% active ingredients and shall otherwise be optional with the manufacturer. It shall contain additives such as coating agents, corrosion inhibitors, etc. as required to produce a product meeting the ~~performance~~ requirements of 3.3.

3.1.1 Composition:

3.1.1.1 Vendor shall submit a complete analytical product chemical by weight analysis, determined in accordance with including ~~weight~~ percentages of major components; ~~by AOAC~~ or ~~ASTM methods~~, ~~and the~~ methods used shall be identified in the test report. Total water content shall be ~~tested by~~ ASTM C ~~871~~. Insolubles shall be ~~reported as analyzed in~~ determined in accordance with 3.2.2.

3.1.1.2 Vendor shall submit a report describing the deicing chemical's ecological behavior to include, but not be limited to, phytotoxicity, impact on groundwater and soils, products of decomposition, ~~and~~ component fates, and BOD.

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3.1.6 Vendor shall submit a report of the deicing compound's ~~chemicals~~ industrial hygiene and toxicology characteristics including, but not limited to, oral and dermal toxicity, plus oral, dermal, ocular and inhalation sensitivity.

3.2 Properties: Properties shall be determined on solutions of 15% active ingredients in the case of solids or at usage strength in the case of fluids.

15% = sample wt (1 - %H20 in sample) / sample wt. + wt. sample dilution H20

3.2.1 The pH of a 15% solution shall be reported.

3.2.2 Insoluble Matter. 30 grams of sample diluted to 200 mL shall be freshly made and maintained at 38°C (100°F) with agitation for one hour. The insoluble matter shall be collected with the aid of a vacuum filtering apparatus consisting of a water tap filter pump, a 2,000 mL Erlenmeyer flask, a size 4, 126 ~~millimeter (mm)~~ mm I.D. Buchner funnel, and a piece of ~~12 centimeter~~ diameter (126 mm) Whatman No. 5 filter paper, or its equivalent. The filter paper shall be dried at 60° ~~Degrees~~ C (140° ~~Degrees~~ F) for 30 minutes in a gravity convection oven, cooled for 3 minutes in a dessicator, and weighed to the nearest 0.1 milligram (mg). The filter paper shall be placed in the Buchner funnel so that its circumference coincides with the circumference of the funnel. The vacuum shall be started and the filter paper wetted with approximately 10 ~~cubic centimeters (cc)~~ mL of distilled water ~~inorder~~ to secure it properly in place. The test sample shall be rinsed with 25 (cc) mL of distilled water from a wash bottle, and the rinse transferred to the funnel, ensuring that any remaining insoluble matter is completely transferred with the rinse. When all the initial liquid and thr rinse have been transferred through the filter, the sides of the funnel shall be washed with 25 mL ~~cc~~ of distilled water from a wash bottle and the rinse allowed to filter. The vacuum of the flask shall be relieved and the filter paper removed from the funnel. The filter paper shall be dried for 1 hour at 60° ~~degrees~~ C (140° ~~degrees~~ F) in a gravity convection over, cooled for 3 minutes in a dessicator, and weighed to the nearest 0.1 milligram ~~mg~~. The percent insolubles shall be calculated as follows:

Final filter paper weight-initial filter paper weight x 100 = % insolubles
Weight of sample

3.1.2.1 Care should be exercised throughout the final drying and weighing cycle to maintain the flat surface of the filter paper in a horizontal position in order that none of the insolubles will be lost. Insoluble matter determinations shall be made on ~~a minimum~~ of not less than fewer two samples.

3.1.3 (3.2.3) The level of soluble chloride shall not exceed 1000 ppm, determined in accordance with ~~Method 112A of~~ APHA Standard Methods for Examination of Water and Wastewater, Method 112A.

3.0 Properties: The deicer compound shall conform to the following requirements. ~~Performance: Performance characteristics shall be determined on a 15% solution as in 3.2, unless otherwise specified.~~ by weight in accordance with specified test methods:

3.0.1 **Corrosion of Metal Surfaces:**

3.0.1.1 **Sandwich Corrosion:** Specimens, after test, shall show a rating not greater than 1 or be worse than synthetic tap water as determined in accordance with ASTM F1110.

3.0.1.2 **Total Immersion Corrosion:** The ~~ESS~~ deicer solution shall neither show evidence of corrosion nor cause a weight change of any test panel greater than the following, determined in accordance with ASTM F483:

Test Panel	Weight Change mg/cm^2 per 24 hours
AMS 4037 Aluminum Alloy, anodized as in AMS 2470	0.3
AMS 4041 Aluminum Alloy	0.3
AMS 4049 Aluminum Alloy	0.3
AMS 4376 Magnesium Alloy, dichromate treated as in AMS 2475	0.2
AMS 4911 Titanium Alloy	0.1
AMS 5045 Carbon Steel ~~ASTM A109~~	0.8

3.0.1.3 **Low Embrittling Cadmium Plate:** Test panels coated with low-embrittling cadmium plate, shall not show a weight change greater than 0.3 mg/cm^2 per 24 hours, determined in accordance with ASTM F1111.

3.~~3.1.5~~ 2.2 **Hydrogen Embrittlement:** The ~~ESS~~ deicer solution shall be non-embrittling, determined in accordance with ASTM F519, Type 1a, 1c or 2a.

3.~~3.2~~ 2.3 **Effect on Transparent Plastic:** The ~~ESS~~ deicer solution shall not craze, stain, or discolor Type C acrylic plastics, determined in accordance with ASTM F484. The shall not craze, stain, or discolor MIL-P-83310 polycarbonate plastic or polysulfone plastic, determined in accordance with test procedures specified in ASTM F484 on specimens stressed for 30 min ± 2 minutes to an outer fiber stress of 3000 psi (20 MPa). 20.7

3.3 **Quality** The ~~solid~~ deicing ~~chemical~~ compound, as received by ~~the~~ purchaser, shall be uniform, free-flowing, and free from foreign materials detrimental to its usage or performance.

4. **QUALITY ASSURANCE PROVISION:**

4.1 **Responsibility for Inspection:** The vendor of the deicing ~~chemical~~ compound shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the deicing ~~chemical~~ compound conforms to the requirements of this specification.

4.2 **Classification of Tests:**

4.2.1 **Acceptance Tests:** Tests to determine conformance to requirements for composition (3.1 and 3.2) are classified as acceptance tests and shall be performed on each lot.

4.2.2 **Periodic Tests:** Tests to determine conformance to requirements for corrosion of metal surfaces (3.3.1), effect on transparent plastic (3.3.2), effect on painted surfaces (3.3.3), are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 INSERT FROM PAGE 8

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 **Sampling:** Shall be in accordance with all applicable requirements of 4.3.1 or 4.3.2; a lot shall be all deicing ~~chemical product~~ compound produced in one continuous manufacturing operation from the same batches of raw materials and presented for vendor's inspection at one time.

4.3.1 **Drum Shipments:** ASTM D1568.

4.3.2 **Bulk Shipments:** ASTM D4057 or ASTM D4177.

4.4 **Approval:**

4.4.1 Sample ~~solid~~ deicing ~~chemical~~ compound shall be approved by purchaser before ~~solid~~ deicing ~~chemical~~ compound for production use is supplied, unless such approval be waived by purchaser. Results of tests on production ~~CMA~~ deicing compound shall be essentially equivalent to those on the approved sample.

4.4.2 Vendor shall use ingredients, manufacturing procedures, and methods of inspection on production ~~solid~~ deicing ~~chemical~~ compound which are essentially the same as those used on the approved sample ~~solid~~ deicing ~~chemical~~ compound. If necessary to make any change in ingredients or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in ingredients and/or ~~material~~, processing, ~~or both~~ and, when requested, sample ~~solid~~ deicing ~~chemical~~ compound. Production ~~solid~~ deicing ~~chemical~~ compound made by the revised procedure shall not be shipped prior to receipt of approval.

4.5 **Reports:** The vendor of ~~solid~~ deicing ~~chemical~~ compound shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance test requirements and, when performed, to the periodic test requirements and stating that the ~~solid~~ deicing ~~chemical~~ compound conforms to the other technical requirements of this specification. This report shall include the purchase order number, lot number, ~~this AMS number~~ AMS ----, manufacturer's identification, and quantity.

4.5.1 A material safety data sheet conforming to AMS 2825, or equivalent, shall be supplied to each purchaser prior to, or concurrent with, the report of preproduction test results or, if preproduction testing be waived by purchaser, concurrent with the first shipment of the ~~solid~~ deicing ~~chemical~~ compound for production use. Each request for modification of ~~solid~~ deicing ~~chemical~~ compound formulation shall be accompanied by a revised data sheet for the proposed formulation.

4.6 **Resampling and Retesting:** If any sample used in the above tests fails to meet the specified requirements, disposition of the ~~solid~~ deicing ~~chemical~~ compound may be based on the results of testing three additional samples for each original nonconforming sample. Failure of any retest sample to meet the specified requirements shall be cause for rejection of the ~~solid~~ deicing ~~chemical~~ compound represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. **PREPARATION FOR DELIVERY:**

5.1 **Packaging and Identification:**

5.1.1 ~~Solid~~ deicing ~~chemicals~~ compound shall be packaged in containers of a type and size agreed upon by purchaser and vendor or shall be delivered in bulk, as ordered.

5.1.2 Each shipment of ~~solid~~ deicing ~~chemical~~ compound shall be legibly marked with not less than AMS ~~1428B~~, purchase order number, lot number, manufacturer's identification, and quantity.

5.1.3 ~~Solid~~ Deicing ~~chemicals~~ compounds shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of ~~solid~~ deicing compound to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

5.1.4 For direct U.S. Military procurement, 794 packaging shall be in accordance with MIL-STD-290, Commercial Level, ~~as in 5.1.1 and 5.1.3~~, unless Level A is specified in the request for procurement.

4.2.3 **Preproduction Tests:** Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests and shall be performed prior to or on the initial shipment of the ~~solid~~ deicing ~~chemical~~ compound to a purchaser, when a change in ingredients, processing, and/or ~~or both~~, requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

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3. **ACKNOWLEDGEMENT:** A vendor shall mention this specification number ~~and its revision number~~ in all quotations and when acknowledging purchasing orders.

7. **REJECTIONS:** ~~Products~~ Deicing compound not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. **NOTES:**

8.1 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and ~~dat~~ date of this specification
Size and type of containers desired
Quantity of ~~deicer~~ deicing compound desired
Applicable level of packaging (See 5.1.4)

8.2 ~~Products~~ Deicing compound meeting the requirements of this specification have been classified under Federal Supply Classification (FSC) 6850.

8.3 This specification is under the jurisdiction of AMS Committee "J" (AMCM).

APPENDIX H

ICE-B-GON (FORMULATION C) CONFORMITY WITH AMS 1426A

SCIENTIFIC MATERIAL INTERNATIONAL INC.

REPLY TO P.O. BOX 141797
CORAL GABLES, FLORIDA 33114
OFFICE: 7019 S.W. 13TH STREET
MIAMI, FLORIDA 33144
PHONE (305) 757-5596
TELEX 4933347 SMI UI
FAX (305) - 893-0431

Chevron Chemical Company
6001Bollinger Caynon Road
San Ramon, California 94582

21 Nov.,88
SMI/REF: 881093

Attn: Mr. Karl Hoenke

Chevron's "C" formulation is for runway use & is different from the highway formulation.

Dear Karl.

Enclosed are the results of Ice B Gon C-10-3-88 tested where applicable to the AMS 1426A format.

The results are reported in this format to show your product does conform to an existing specification now in use. Please note the following. The product in its dry form is not considered slippery. In the wet form the product when tested on the NBS Portable Slipperiness shows a coefficient of friction of .46. This is within guide lines of not being less than .25.

(note)

Please note the following:

SMI has not received a signed copy of the contract..

SMI has not received payment of SMI/REF: 880870 dated 23 Aug.88 $6,411.00.

If i may be of further assistance to you in this regard,please feel free to contact me.

Respectfully submitted,

Joseph Schruefer,Jr.

SCIENTIFIC MATERIAL INTERNATIONAL INC.

REPLY TO P.O. BOX 141797
CORAL GABLES, FLORIDA 33114
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Chevron Chemical Company
6001 Bollinger Caynon Road
San Ramon, California 94582

21 Nov.,88
SMI/REF: 881093

Attn: Mr. Karl Hoenke

Product" Ice B Gon C-10-3-88

Dilution: 1 part product,14 parts water

All tests conducted on the diluted solution.

AMS 1426A
Deicing/Anti-icing Fluid
Runways and Taxiways

3.1	Material	Calcium Magnesium Acetate
3.2.1.1	Specific Gravity	Powder sample
3.2.2	pH	Qualification value
3.2.3	Flash point	Conform
3.2.4	Eutectic Point	Powder sample Does not apply
3.2.5.1	Sandwich Corrosion	Conform
3.2.5.2	Total Immersion Corrosion	Conform
3.2.5.3	Low -Embrittling Cadmium	Conform
3.2.6	Hydrogen Embrittlement	Conform
3.2.7	Effect on Transparent Plastics	Conform
3.2.8	Effect on Painted Surfaces	Conform
3.2.9	Effect on Unpainted Surfaces	Conform
3.2.10.1	Rinsibility	Conform
3.2.11.1	Scaling Resistance	Conform
3.2.11.2	Slipperiness	Conform

Respectfully submitted,

Joseph Schruefer,Jr.

3.1 Technical Requirements:

3.1 Material: The composition of the fluid shall be optional with the manufacturer but shall contain glycol, urea, formamide and corrosion inhibitors as required to produce a product meeting the requirements of 3.2.

Result CMA powder

3.2 Properties: The fluid shall conform to the following requirements; tests shall be performed in accordance with specified test methods on the product supplied in concentrated form:

3.2.1 Specific Gravity: Shall be within +0.005 of the qualification value established as in 4.4.1, determined in accordance with ASTM D 891.

Result Powder sample does not apply

3.2.2 pH: Shall be within +0.5 of the qualification value established as in 4.4.1, determined in accordance with ASTM E70.

8.4 pH (1:5 solution)

Result Qualification value

3.2.3 Flash Point: Shall not lower than 100°C(212°F), determined in accordance with ASTM D56 or ASTM D3278. In case of conflict, flash point determined in accordance with ASTM D 56 shall apply.

Result Conform no flash

3.2.4 Eutectic Point (Slush or Freeze Point: Shall be not higher than -23°C)-10°F), determined in accordance with ASTM D1177.

Result Powder sample does not apply

3.2.5 Corrosion of Metal Surfaces:

3.2.5.1 Sandwich Corrosion: Specimens of AMS 4037 and AMS 4049 aluminum alloy, after test, shall show a rating not worse than 2, determined in accordance with ARP 1512.

4037 Pass
4049 Pass

Result Conform

3.2.5.2 Total Immersion Corrosion: The fluid shall neither sho evidence of corrosion nor cause a weight change of any single test panel greater than the following,determined in accordance with ASTM F 483:

Test Panel	Weight change mg/cm^2/24hr	Result
AMS 4037 or QQ-A-250/4 Al alloy anodized as in AMS 2470	0.3	-.14
AMS 4041 or QQ-A-250/5 Al alloy (optional)	0.3	-.12
AMS 4049 or QQ-A-250/13 Al alloy	0.3	-.10
AMS 4376 or QQ-M-44,alloy AZ31B,Mg alloy dichromate treated as in AMS 2475	0.2	-.13
AMS 4911 or Mil-T-9046,Type III Composition C,Titanium alloy	0.1	-.09
ASTM A109,Temper No.1 or QQ-S-698, condition 1,Steel	0.8	-.11

Result Conform

3.2.5.3 Low-Embrittling Cadmium Plate:Test panels coated with low-embrittling Cadmium plate shall not show a weight change greater than 0.3 (mg/cm^2) 24hr, determined in accordance with ARP 1511.

.15mg/cm^2/24hr
Result Conform

3.2.6 Hydrogen Embrittlement: The fluid shall be non-embrittling,determined in accordance with ASTM F-519,Method 2a

Result Conform

3.2.7 Effect on Transparent Plasties: The fluid shall not craze,stain, or discolor Type C acrylic plastic,determined in accordance with ASTM F 484. The fluid shall not craze,stain or discolor Mil-P-83310 polycarbonate plastic or polysulfone plastic, determined in accordance with test procedures specified in ASTM F 484 on specimens stressed for 30 minutes ± 2 to an outer fiber stress of 3000 psi (20 MPa).

Result Conform

3.2.8 Effect on Painted Surfaces: The fluid shall neither decrease the paint film hardness by more than two pencil hardness levels nor shall it produce any streaking, discoloration, or blistering of the paint film, determined in accordance with ASTM F502.

Result Conform

3.2.9 Effect on Unpainted Surfaces: The fluid, tested in accordance with ASTM F485, shall neither produce streaking nor leave any stains requiring polishing to remove.

Result Conform

3.2.10 Rinsibility: The fluid shall be completely rinsible in tap water, determined in accordance with 3.2.10.1.

3.2.10.1 A 75X200 (3X8 in.) panel of clear glass shall be cleaned to provide a surface free of waterbreak, dried, and coated with the deicer/anti-icer fluid by pouring the fluid over the panel while it is held in a horizontal position. The coated panel shall be inclined at approximately 45 deg for 10 min.± 0.5, then placed in a horizontal position for 24 hr± 0.25 at room temperature. After the 24 hr exposure, the panel shall be rinsed in tap water for 5-6 min., rinsed in distilled or deionized water, dried, and examined for visible traces of the deicer/anti-icer fluid.

Result Conform

3.2.11 Pavement Compatibility:

3.2.11.1 Scaling Resistance: . The condition of the surface shall have a rating not greater than 2, determined in accordance with ASTM C672 except that a 25% by volume solution of the deicer/anti-icer fluid in tap water shall be substituted for calcium chloride.

Product tested as a 25% slurry Result Conform rating of 1

3.2.11.2 Slipperiness: Friction limits shall be as follows, determined on concrete and asphalt surfaces, both wet and dry, using a Mu meter and with a deicer/anti-icer fluid thickness of 1 mm (0.04 in.) using a NASA depth gauge. A basis reading shall be determined on wet and dry concrete and wet and dry asphalt before application of the deicer/anti-icer fluid.

Test dry and wet. Using a portable slipperiness tester NBS . All readings above .25 coeficcient of friction.

Result Not considered slippery